PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 17: ORGANIC CHEMISTRY II

SCORE	PERCENTAGE
/486	%

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Q1. Select the correct pH for each of the following solutions.

(a) Nitric acid, HNO_3, of concentration 2 mol dm^{-3}, assuming it is fully dissociated.

(1)

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

A −0.3

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

B 0.0

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

C 0.3

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

D 2.0

(b) Sodium hydroxide, NaOH, of concentration 2 mol dm^{-3}, using $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}

(1)

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

A −13.7

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

B 13.7

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

C 14.0

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

D 14.3

(c) Ethanoic acid, CH_3COOH, of concentration 2 mol dm^{-3}, making the usual assumptions.

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

(1)

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

A 2.2

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5} \text{ mol dm}^{-3}$$

B 2.4

$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5}$ mol dm^{-3}

C 4.5

$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5}$ mol dm^{-3}

D 4.8

(d) The mixture formed when 25 cm^3 of 2 mol dm^{-3} sodium hydroxide solution is added to 50 cm^3 of 2 mol dm^{-3} ethanoic acid, for which $K_a = 1.7 \times 10^{-5}$ mol dm^{-3}.

(1)

$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5}$ mol dm^{-3}

A 2.2

$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5}$ mol dm^{-3}

B 2.5

$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5}$ mol dm^{-3}

C 4.5

$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = 1.7 \times 10^{-5}$ mol dm^{-3}

D 4.8

(Total for Question = 4 marks)

Q2.

This question is about an experiment to determine the equilibrium constant, K_c , for an esterification reaction producing propyl ethanoate. The equation for the reaction is

$$\underset{\text{ethanoic acid}}{CH_3COOH(l)} + \underset{\text{propan-1-ol}}{CH_3CH_2CH_2OH(l)} \rightleftharpoons \underset{\text{propyl ethanoate}}{CH_3COOCH_2CH_2CH_3(l)} + H_2O(l)$$

In an experiment to determine the equilibrium constant, K_c , the following steps were carried out.

- 6.0 cm^3 of ethanoic acid (0.105 mol), 6.0 cm^3 of propan-1-ol (0.080 mol) and 2.0 cm^3 of dilute hydrochloric acid were mixed together in a sealed boiling tube.
  In this pre-equilibrium mixture, there is 0.111 mol of water
- The mixture was left for one week, at room temperature and pressure, to reach equilibrium
- The equilibrium mixture and washings were transferred to a volumetric flask and the solution made up to exactly 250.0 cm^3 using distilled water
- 25.0 cm^3 samples of the **diluted** equilibrium mixture were titrated with a solution of sodium hydroxide, concentration 0.200 mol dm^{-3}, using phenolphthalein as the indicator
- The mean titre was 23.60 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution.

(a) State the role of the hydrochloric acid in the esterification reaction.

(1)

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(b) (i) Calculate the total amount, in moles, of acid present in the **volumetric flask** in the equilibrium mixture.

(2)

(ii) The 2.0 cm^3 of dilute hydrochloric acid contained 0.00400 mol of $H^+(aq)$ ions.

Use this and your answer to part (b)(i) to calculate the amount, in moles, of ethanoic acid present in the equilibrium mixture.

(1)

(c) (i) The initial mixture in the boiling tube contained 0.105 mol of ethanoic acid.

Use your answer to (b)(ii) to calculate the amount, in moles, of ethanoic acid that reacted to form the ester in the equilibrium mixture.

(1)

(ii) Use information given in the method, and your answer to (c)(i), to calculate the amounts, in moles, of propan-1-ol, propyl ethanoate and water that are present in the equilibrium mixture.

(3)

Moles of propan-1-ol at equilibrium

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Moles of propyl ethanoate at equilibrium

.....

Moles of water at equilibrium

.....

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

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$

(1)

(ii) Explain why it is possible, in this case, to calculate K_c using equilibrium amounts in moles, rather than equilibrium concentrations.

(2)

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(iii) Calculate the value of K_c.

Give your answer to an appropriate number of significant figures.

(2)

(e) The pink colour of the phenolphthalein fades after the end-point of the titration has been reached.

Give a possible explanation for this observation.

(2)

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(f) Explain what you could do to confirm that one week is sufficient time for the mixture to reach equilibrium.

(2)

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(g) A student repeated the experiment, but left the mixture in a water bath at 40 °C until equilibrium was reached.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l) \qquad \Delta_r H^{\ominus} = +21.4\,kJ\,mol^{-1}$$

Deduce the effect, if any, on this student's value for K_c compared with that obtained in part (d)(iii).

(2)

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(Total for question = 19 marks)

Q3.

This question is about some carbonyl compounds with the molecular formula $C_5H_{10}O$.

An aldehyde with molecular formula $C_5H_{10}O$ has a ^{13}C NMR spectrum with three peaks.

The high resolution ^{1}H NMR spectrum of this aldehyde has two peaks and neither of them is split.

Deduce the **displayed** formula of this aldehyde.
Justify your answer by referring to both NMR spectra.

(4)

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(Total for question = 4 marks)

Q4.

An organic compound, **X**, was analyzed in a laboratory.

(a) Compound **X** was found to have the following percentage composition by mass:

carbon, C = 54.5%

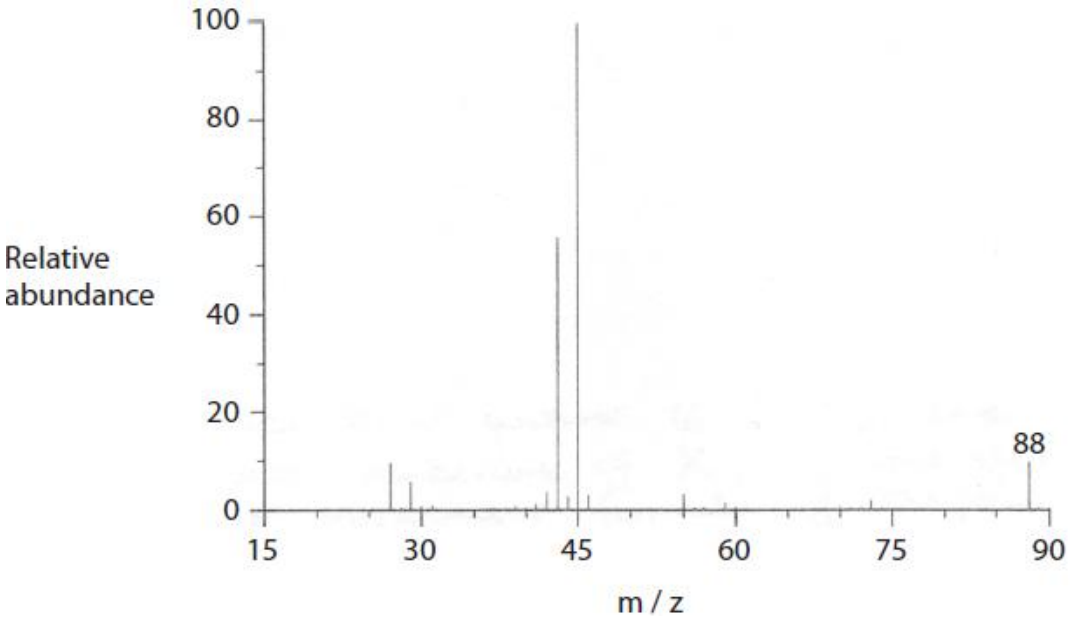
hydrogen, H = 9.1%

oxygen, O = 36.4%

(i) Use these data to calculate the empirical formula of compound **X**, showing your working.

(2)

(ii) The mass spectrum of **X** is shown below.



Use your answer to (a)(i), and the mass spectrum of **X**, to show that the molecular formula of compound **X** is $C_4H_8O_2$.

(2)

(b) The infrared spectrum of **X** has a broad peak at approximately 3500 cm^{-1} and a sharp peak at approximately 1700 cm^{-1}. Identify the **bond** responsible for the peak at

(2)

3500 cm^{-1}

1700 cm^{-1}

(c) (i) Some chemical information about compound **X** is given below.

- **X** is a neutral organic compound.
- **X** has no effect on Tollens' reagent.
- **X** turns hot acidified potassium dichromate(VI) solution from orange to green.

What does each of these three pieces of information suggest about the nature of **X**?

(4)

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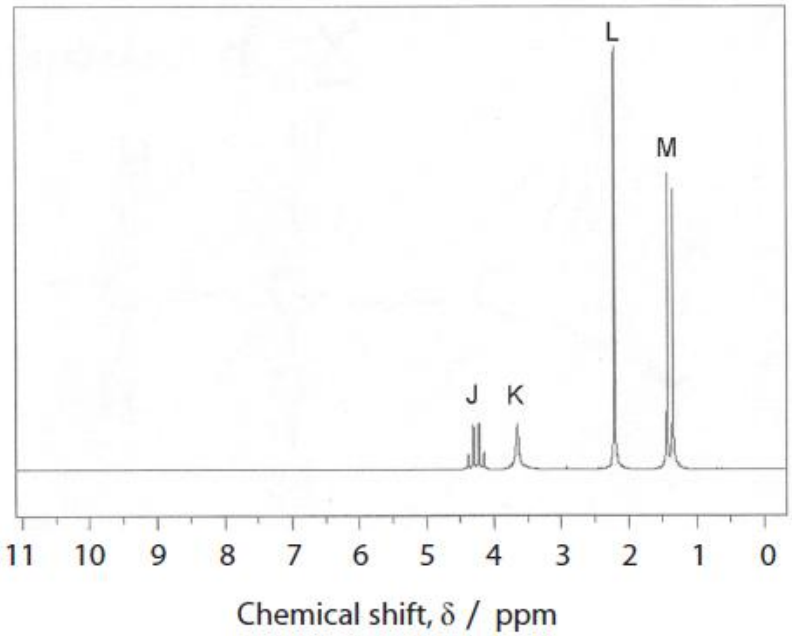
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(ii) Use your answers to parts (b) and (c)(i) to name the two functional groups present in **X**.

(1)

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*(d) The high resolution proton nmr spectrum of **X** is shown below.



The relative number of protons causing the peaks shown are: J = 1, K = 1, L = 3 and M = 3.

Use the information above to determine the structural formula of **X**.

In your answer, you should refer to the number of peaks, their relative sizes and their splitting patterns.

(7)

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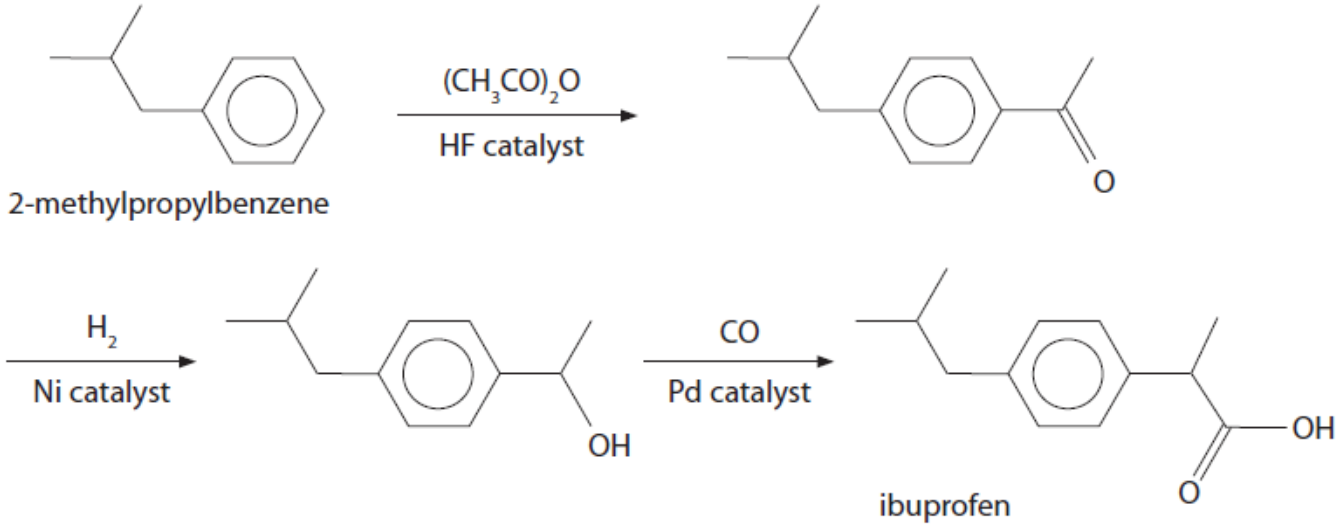
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(Total for question = 18 marks)

Q5.

Ibuprofen is a nonsteroidal anti-inflammatory drug (NSAID) widely used as an analgesic (pain reliever). It was discovered in the 1960s by the Boots Group which developed a six step synthesis from 2-methylpropylbenzene. The synthesis shown below was introduced in the 1990s by the BHC Company and received a Presidential Green Chemistry Challenge award in 1997. The citation noted that the synthesis has just three steps, all of which are catalytic, and an effective atom economy of 99%. Both syntheses are carried out in solution.



(a) (i) Suggest why a three step synthesis is likely to be 'greener' than a six step process.

(1)

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.....

(ii) Why does the use of catalysts make processes 'greener' (as well as faster)?

(1)

.....

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(b) The first step of the synthesis is an electrophilic substitution which is usually carried out in a school laboratory using ethanoyl chloride and an aluminium chloride catalyst.

(i) Write an equation showing the formation of the electrophile in the **school** experiment.

(1)

(ii) Give the mechanism for the electrophilic substitution of 2-methylpropylbenzene by ethanoyl chloride, using the electrophile you have given in (b)(i).

(3)

(iii) Suggest **one** environmental benefit of using $(CH_3CO)_2O$, rather than ethanoyl chloride, in the manufacture of ibuprofen.

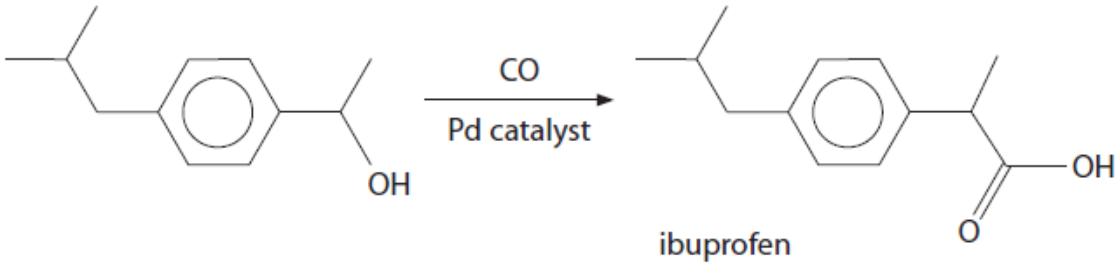
(1)

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(c) The final stage of the modern synthesis for ibuprofen is shown below.



ibuprofen

(i) Suggest a benefit of using a **solid** catalyst in this reaction.

(1)

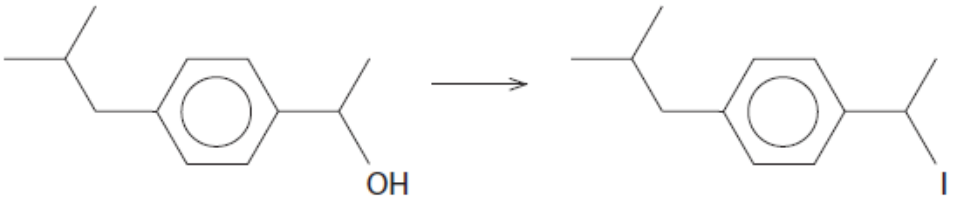
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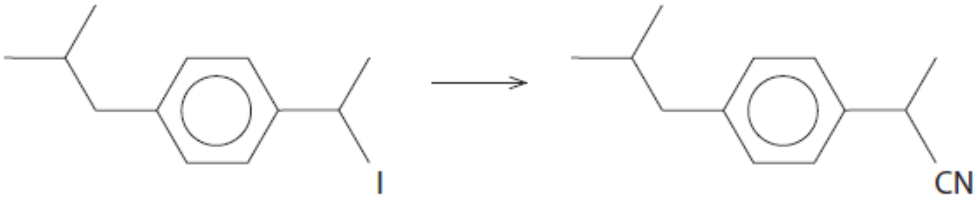
(ii) The preparation in part (c) can be carried out in a laboratory in three reactions.

(3)

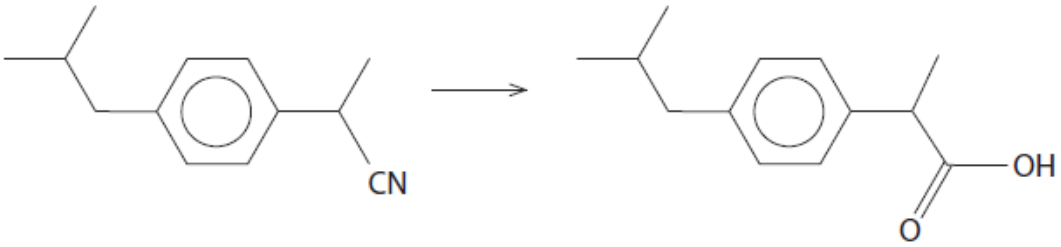
Reaction 1



Reaction 2



Reaction 3



Give:

The reagents for **Reaction 1**

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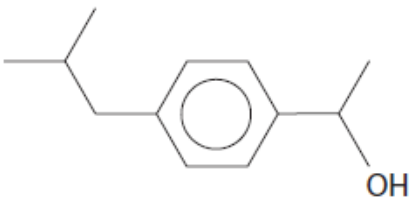
The reagents and conditions for **Reaction 3**

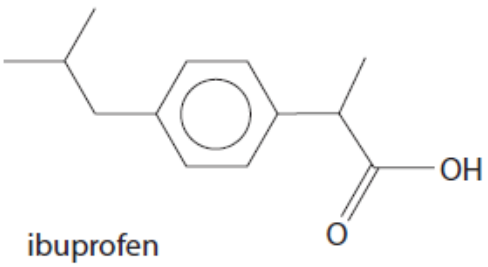
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(iii) Using your Data Booklet, explain how infrared spectroscopy can be used to distinguish between the two structures shown below.

(2)





ibuprofen

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(d) Ibuprofen is a chiral molecule and only one of its enantiomers is biologically active. However, although the synthesis produces a racemic mixture, an isomerase enzyme in the body converts the inactive enantiomer into the active enantiomer.

(i) Explain the term 'chiral molecule'.

(1)

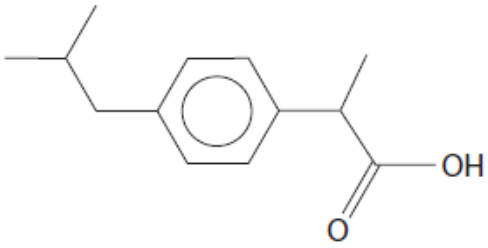
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(ii) Mark with an asterisk (*) the chiral centre on the structure of ibuprofen below.

(1)



(iii) Explain the term 'racemic mixture'.

(1)

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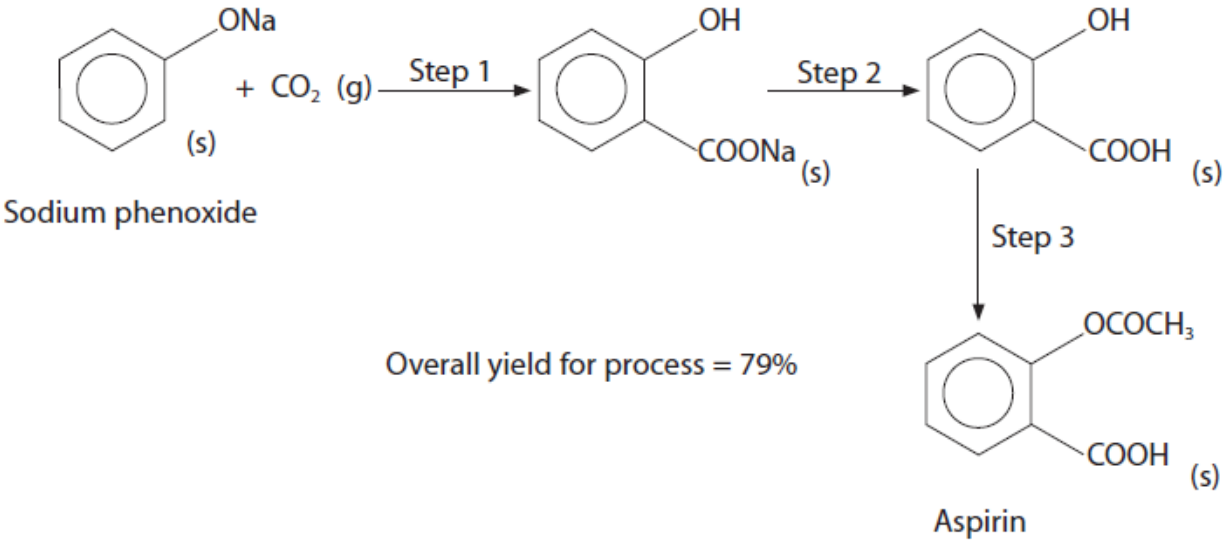
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(Total for question = 16 marks)

Q6.

Aspirin can be manufactured from sodium phenoxide using the process shown below.



Sodium phenoxide

Overall yield for process = 79%

Aspirin

(a) Explain **one** effect of an increase in pressure on the reaction in Step 1.

(2)

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(b) The overall yield for this process is 79%.

Calculate the mass, in tonnes, of aspirin that would be formed from 2.5 tonnes of sodium phenoxide. Give your answer to **two** significant figures.

[Molar masses / g mol^{-1}: sodium phenoxide = 116; aspirin = 180]

(3)

(c) Classify the reaction type in Step 3 and suggest a suitable reagent.

(2)

Reaction type

.....

Reagent

.....

(Total for question = 7 marks)

Q7.

Fresh coffee is made by adding hot water to ground coffee beans.

Chemists at the University of Nevada have produced bio-diesel fuel from used coffee grounds. The grounds contain approximately 10–15% oil by mass. This oil can be extracted, using standard chemical techniques, and then converted to bio-diesel by the reaction with methanol in the presence of a suitable catalyst.

(a) (i) A solvent is added to the solid coffee grounds to dissolve the oil. Suggest how the oil is then obtained from this mixture.

(2)

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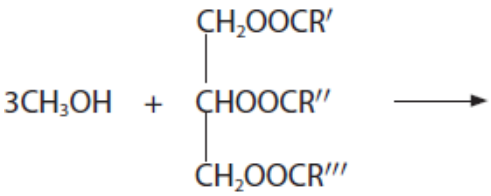
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(ii) Complete the equation below for the formation of a bio-diesel from the reaction of an oil with methanol.

(2)



(iii) Suggest a suitable catalyst for the reaction in (ii).

(1)

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*(b) Another source of oil for bio-diesel production is palm oil, obtained from the fruit of palm trees grown on large plantations across many tropical regions.

Consider **one** advantage and **one** disadvantage of each source to decide which oil may provide a potentially greener and more sustainable supply of bio-diesel.

(4)

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(Total for question = 9 marks)

Q8.

This is a question about polymerisation.

PLA is a biodegradable polyester which is made from 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$.

(i) Draw the two enantiomers of 2-hydroxypropanoic acid.

(2)

(ii) State how separate samples of these two enantiomers could be distinguished in a laboratory.

(1)

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.....

(iii) Biodegradable polyesters break down naturally.

State why this is an advantage.

(1)

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(Total for question = 4 marks)

Q9.

This question is about a dicarboxylic acid **Y** which is present in some citrus fruits.
Y contains only the elements carbon, hydrogen and oxygen.

A solution was prepared using 4.34 g of the dicarboxylic acid **Y** made up to a volume of 250 cm^3 with distilled water.

A 25.0 cm^3 sample of this solution was then titrated using sodium hydroxide solution, NaOH(aq), of concentration 0.320 mol dm^{-3}.

The mean titre of sodium hydroxide solution was 26.10 cm^3.

Calculate the molar mass of **Y** using the titration data, and hence deduce its structure. You must show your working.

(5)

(Total for question = 5 marks)

Q10. An organic compound reacts with **both** acidified potassium dichromate(VI) **and** lithium tetrahydridoaluminate (lithium aluminium hydride). The organic compound could be

☒ **A** a primary alcohol.

☒ **B** an aldehyde.

☒ **C** a ketone.

☒ **D** a carboxylic acid.

(Total for Question = 1 mark)

Q11. Ketones react with

☒ **A** both 2,4-dinitrophenylhydrazine solution and Tollens' reagent.

☒ **B** 2,4-dinitrophenylhydrazine solution but not with Tollens' reagent.

☒ **C** Tollens' reagent but not with 2,4-dinitrophenylhydrazine solution.

☒ **D** neither Tollens' reagent nor 2,4-dinitrophenylhydrazine solution.

(Total for Question = 1 mark)

Q12. A solution of 2,4-dinitrophenylhydrazine (Brady's reagent) is used as a test for organic functional groups.

(a) The positive result of the test is the formation of

(1)

= **A** a yellow solution.

= **B** an orange precipitate.

= **C** a red solution.

= **D** a green precipitate.

(b) Which of the following gives a positive result with a solution of 2,4-dinitrophenylhydrazine?

(1)

= **A** Only aldehydes

= **B** Only ketones

= **C** Only aldehydes and ketones

= **D** Any compound containing the C=O group

(c) The initial attack by 2,4-dinitrophenylhydrazine, when it reacts, is by

(1)

= **A** a free radical.

= **B** an electrophile.

= **C** a nucleophile.

= **D** a negative ion.

(d) The product of a positive test, a 2,4-dinitrophenylhydrazone, contains which of the following bonds?

(1)

= **A** N=N

= **B** C=N

= **C** C=C

= **D** C=O

(Total for Question = 4 marks)

Q13. This question is about the following isomeric compounds with the molecular formula C_4H_8O and molar mass 72 g mol^{-1}.

A $CH_3CH_2CH_2CHO$

B $(CH_3)_2CHCHO$

C $CH_3CH_2COCH_3$

D $CH_3CH=CHCH_2OH$

(a) Which compound would you expect to give a peak at *m*/*e* = 41 in its mass spectrum?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which compound would NOT react with an acidified solution of potassium dichromate(VI)?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which compound would give a pale yellow precipitate when reacted with iodine in alkaline solution?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) Which compound can be reduced to give a chiral product?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(e) Which compound would NOT react with hydrogen cyanide under suitable conditions to form a hydroxynitrile?

(1)

☒ **A**

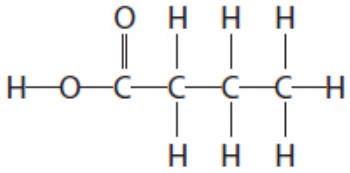
☒ **B**

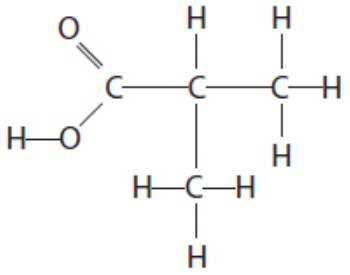
☒ **C**

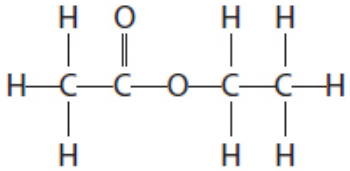
☒ **D**

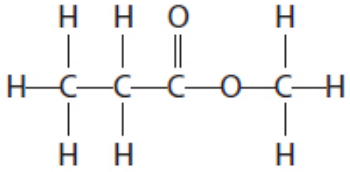
(Total for Question = 5 marks)

Q14. Propanoic acid reacts with methanol to form an ester. The structure of the ester is

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question = 1 mark)

Q15. Transesterification involves the conversion of

☒ **A** esters into different esters.

☒ **B** esters into carboxylic acids.

☒ **C** *cis* carbon-carbon double bonds to the *trans* arrangement.

☒ **D** *trans* carbon-carbon double bonds to the *cis* arrangement.

(Total for Question = 1 mark)

Q16. Biodiesel is formed by transesterification. It is used as a fuel in preference to untreated vegetable oils because

☒ **A** on combustion, biodiesel produces less carbon dioxide than vegetable oils.

☒ **B** on combustion, biodiesel produces more energy than vegetable oils.

☒ **C** biodiesel vaporises more easily than vegetable oils.

☒ **D** biodiesel is less volatile than vegetable oils.

(Total for Question = 1 mark)

Q17. Ethanoic acid, CH_3COOH, may be prepared from ethanenitrile, CH_3CN. This reaction is best described as

☒ **A** reduction.

☒ **B** oxidation.

☒ **C** hydrolysis.

☒ **D** condensation.

(Total for Question = 1 mark)

Q18. This question is about the reactions of butanoic acid, $CH_3CH_2CH_2COOH$. It has a foul smell and behaves like a typical carboxylic acid.

(a) (i) The addition of sodium carbonate solution is often used as a chemical test to distinguish carboxylic acids, like butanoic acid, from other compounds, such as aldehydes.

Explain why old stocks of aldehydes often react with sodium carbonate solution.

(1)

.....

.....

(ii) How would the result of this test distinguish between a carboxylic acid and an old stock of an aldehyde?

(1)

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(iii) Write the balanced chemical equation, including state symbols, for the reaction of sodium carbonate solution with butanoic acid.

(2)

*(iv) Infrared spectroscopy is a good physical method to distinguish carboxylic acids from other organic compounds. Give the wavenumbers of **two** characteristic absorptions for a carboxylic acid. Indicate the bond responsible for each absorption. Suggest why one of the absorptions is broad.

(3)

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(v) High resolution nuclear magnetic resonance spectroscopy is a suitable physical method to use alongside infrared spectroscopy to identify butanoic acid. State the total number of peaks and suggest the splitting pattern for each peak that you would expect for butanoic acid, $CH_3CH_2CH_2COOH$.

(3)

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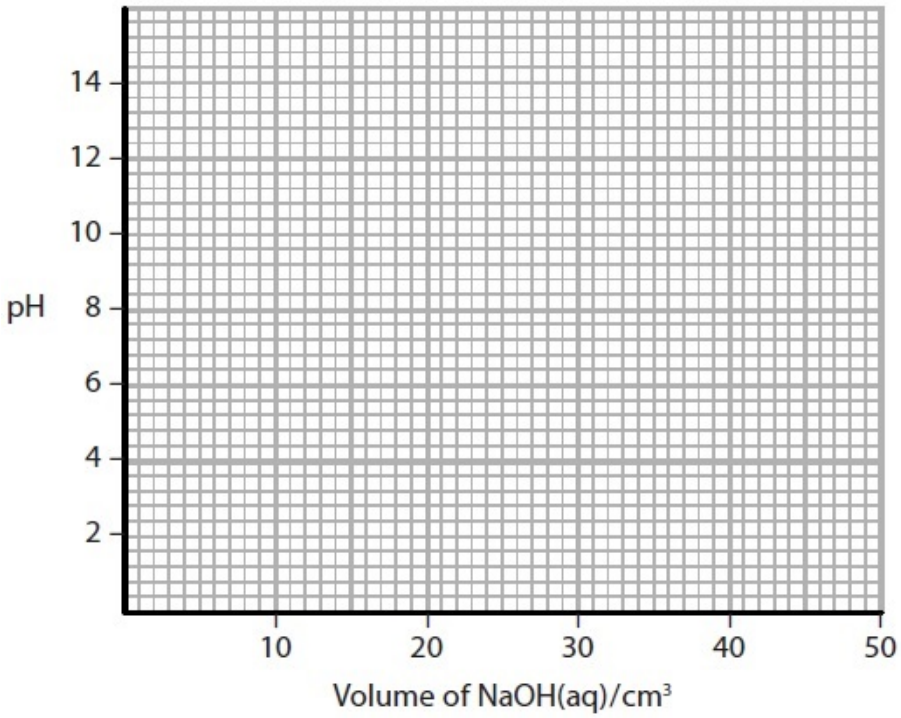
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(b) Sketch the titration curve obtained when 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide solution is added to 25 cm^3 of 0.10 mol dm^{-3} butanoic acid.

(4)



(c) (i) What would you see when phosphorus pentachloride, PCl_5, reacts with butanoic acid?

(1)

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(ii) Give the structural formula and name of the organic product of this reaction.

(2)

Structural formula

Name

.....

(d) (i) Give the name or formula of the organic product of the reaction between butanoic acid and lithium tetrahydridoaluminate (lithium aluminium hydride).

(1)

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(ii) Water cannot be used as the solvent in this reaction because it reacts with lithium tetrahydridoaluminate. Suggest a suitable solvent.

(1)

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(iii) State the type of reaction that takes place between butanoic acid and lithium tetrahydridoaluminate. Justify your classification.

(2)

Type

.....

Justification

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.....

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(e) (i) Butanoic acid can be reacted with methanol to make methyl butanoate. State **two** conditions that help to speed up this reaction.

(2)

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(ii) Draw the **displayed** formula of methyl butanoate.

(1)

(iii) Identify another chemical, by name or formula, which could be added to methanol to make methyl butanoate.

(1)

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*(iv) Give **two** advantages and **one** disadvantage of using the reaction occurring in (e)(iii), compared to the reaction in (e)(i), when making methyl butanoate.

(3)

Advantages

.....

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Disadvantage

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(Total for Question = 28 marks)

Q19. The boiling temperature of ethanoic acid is very much higher than that of butane although these molecules have similar numbers of electrons. This is because ethanoic acid has

☒ **A** stronger covalent bonds.

☒ **B** stronger ionic bonds.

☒ **C** greater London forces.

☒ **D** hydrogen bonding.

(Total for Question = 1 mark)

Q20.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.



A **B**

Deduce a **chemical** test which would give a positive result for **B** but **not** for **A**.
Include the reagent and observation.

(2)

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(Total for question = 2 marks)

Q21.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.



A **B**

Deduce a **chemical** test which would give a positive result for **A** but **not** for **B**.
Include the reagent and observation.

(2)

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(Total for question = 2 marks)

Q22.

This is a question about the hydrolysis of halogenoalkanes.

The product of the hydrolysis of 2-bromobutane is butan-2-ol. Both molecules are chiral.

State what is meant by the term chiral, using three-dimensional diagrams of the enantiomers of butan-2-ol to illustrate your answer.

(3)

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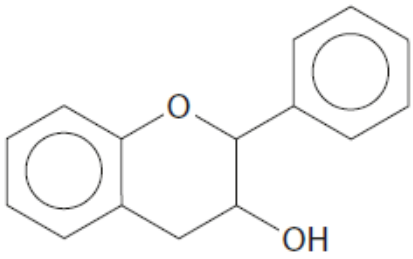
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(Total for question = 3 marks)

Q23.

The compound flavan-3-ol is found in tea, fruit and wine.



Clearly label all the chiral carbon atoms in flavan-3-ol.

(Total for question = 1 mark)

Q24. Select the word that best describes the effect of a chiral molecule on the plane of plane-polarized light. The plane of polarization of light is

☒ **A** reflected.

☒ **B** refracted.

☒ **C** resolved.

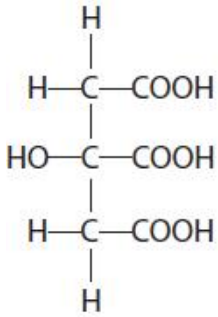
☒ **D** rotated.

(Total for Question = 1 mark)

Q25.

Citric acid is found in lemon juice.

The structure and formula of citric acid are shown below.



$C_6H_8O_7$

(a) In the presence of a small amount of moisture, citric acid reacts with sodium hydrogencarbonate as shown in the equation below.

$$C_6H_8O_7(s) + 3NaHCO_3(s) \rightarrow Na_3C_6H_5O_7(s) + 3CO_2(g) + 3H_2O(l)$$

Use the structural formula of citric acid to explain why one mole of citric acid neutralizes three moles of sodium hydrogencarbonate.

(1)

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(b) You will need to refer to the data booklet in the calculations which follow.

You should also use the values given below.

compound	$S^{\ominus}$ / J mol^{-1} K^{-1}
$Na_3C_6H_5O_7(s)$	200.5
$C_6H_8O_7(s)$	199.9

(i) Calculate the standard entropy change of the system, $\Delta S^{\ominus}_{system}$, for the following reaction at 298 K. Include a sign and units in your answer.

(2)

$$C_6H_8O_7(s) + 3NaHCO_3(s) \rightarrow Na_3C_6H_5O_7(s) + 3CO_2(g) + 3H_2O(l)$$

*(ii) Explain how the sign of your answer to (b)(i) could be predicted from the equation for the reaction between citric acid and sodium hydrogencarbonate.

(2)

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(iii) Given that $\Delta H^{\ominus}_{298}$ for the reaction shown in (b)(i) is +70 kJ mol^{-1}, calculate the standard entropy change of the surroundings, $\Delta S^{\ominus}_{surroundings}$, for this reaction at 298 K. Include a sign and units in your answer.

(2)

(iv) Calculate the total entropy change, $\Delta S^{\ominus}_{total}$, for this reaction at 298 K.

(1)

(v) What does the sign of $\Delta S^{\ominus}_{total}$ suggest about this reaction at 298 K?

(1)

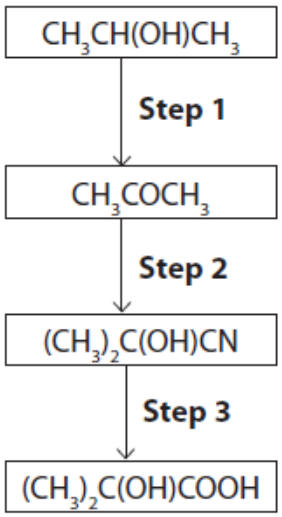
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(Total for question = 9 marks)

Q26.

A flow chart for making 2-hydroxy-2-methylpropanoic acid from propan-2-ol is shown below.



(a) (i) Give the reagents and conditions for **Step 1**.

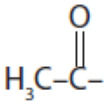
(2)

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(ii) Propanone is formed in Step 1.

Give a chemical test to identify the carbonyl group and a further test to show the presence of the  group.

For both tests, give the observations that you would make.

(4)

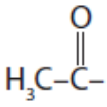
Carbonyl group

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 group

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(b) (i) In **Step 2**, propanone undergoes an addition reaction with HCN in the presence of CN^- ions.
Give the mechanism for this reaction.

(3)

(ii) Explain why this reaction would not take place at either a very low or very high pH.

(2)

Low pH

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High pH

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(c) (i) The reaction in **Step 3** forms 2-hydroxy-2-methylpropanoic acid, $(CH_3)_2C(OH)COOH$. Suggest the type of reaction occurring in **Step 3**.

(1)

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(ii) Explain why the presence of the alcoholic hydroxyl group cannot be confirmed in the infrared spectrum of 2-hydroxy-2-methylpropanoic acid.

(1)

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(iii) The hydrogen of the alcohol group in 2-hydroxy-2-methylpropanoic acid can be identified by a single peak in the nmr spectrum.

Give the chemical shift you would expect for this peak.

(1)

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(iv) How many peaks would you expect in a high resolution nmr spectrum for 2-hydroxy-2-methylpropanoic acid, $(CH_3)_2C(OH)COOH$?

(1)

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(v) Explain why, in high resolution nmr, the peak due to the hydrogens of the 2-methyl group in 2-hydroxy-2-methylpropanoic acid is a singlet.

(1)

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(vi) Would you expect 2-hydroxy-2-methylpropanoic acid to have optical isomers? Justify your answer.

(1)

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(d) (i) Molecules of 2-hydroxy-2-methylpropanoic acid react together to form a condensation

polymer.

Draw a **displayed** formula for this polymer, showing two repeating units.

(2)

(ii) Give the name of the functional group that links the two molecules in the polymer.

(1)

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(Total for question = 20 marks)

Q27.

A compound **Q** contains carbon, hydrogen and oxygen only.
It has a molar mass of 148 g mol^{-1}.

(a) Combustion analysis shows that when 0.952 g of **Q** is completely burned in excess oxygen, 2.83 g of carbon dioxide and 0.693 g of water are formed.

Use these data to determine the molecular formula of **Q**.

(5)

(b) Three qualitative tests are carried out on **Q**.
The results of each test are given in parts (i), (ii) and (iii).

State what can be deduced from each of these results.

(i) A very sooty flame is observed when a small sample of **Q** is burned in air.

(1)

.....

(ii) A yellow-orange precipitate is observed when a small amount of 2,4-dinitrophenylhydrazine is added to **Q**.

(1)

.....

(iii) No visible change is observed when a sample of **Q** is warmed with Tollens' reagent.

(1)

.....

(c) These data come from the proton NMR spectrum of **Q**.

Chemical shift of peak / ppm	Splitting pattern	Area under peak
7.5	complex multiplet	5
2.55	septuplet	1
1.25	doublet	6

(i) Deduce the structure of **Q**, using these data and your answers to (a) and (b).

Justify how all the data in the table supports your answer.

(7)

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(Total for question = 15 marks)

Q28.

This question is about an experiment to determine the equilibrium constant, K_c, for the reaction between ethanoic acid and ethanol to form ethyl ethanoate and water.

Two sealed test tubes were prepared.

The first test tube contained 0.0400 mol ethanoic acid, 0.0400 mol of ethanol and 0.20 cm^3 of

concentrated hydrochloric acid.

The second test tube contained 0.0400 mol ethyl ethanoate, 0.0400 mol of water and 0.20 cm^3 of concentrated hydrochloric acid.

After standing at 25°C for two weeks, to ensure equilibrium is reached, the contents of each test tube were separately titrated with 0.200 mol dm^{-3} sodium hydroxide solution.

0.20 cm^3 of concentrated hydrochloric acid was also titrated with the same sodium hydroxide solution.

(a) (i) Using data from the Data Booklet, calculate the volume, in cm^3, of 0.0400 mol of ethanoic acid.

(2)

(ii) What would be the best piece of apparatus to measure out the volumes of the liquids for the sealed test tubes?

(1)

.....

(iii) Suggest a reason why the test tubes were sealed.

(1)

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.....

(iv) Suggest a suitable indicator for the titration of the equilibrium mixture in either test tube, with the expected colour change. Justify your suggestion.

(3)

Indicator

.....

Colour change from ..... to .....

Justification

.....

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(b) In this experiment, the following titres were obtained.

Titration	Volume of 0.200 mol dm^{-3} sodium hydroxide solution/cm^3
Contents of first test tube	77.10
Contents of second test tube	77.05
0.20 cm^3 concentrated hydrochloric acid	11.70

(i) Write the equation for the reaction between ethanoic acid and ethanol to form ethyl ethanoate and water, using structural formulae. State symbols are not required.

(1)

(ii) Calculate the number of moles of ethanoic acid present at equilibrium in the first test tube.

(2)

(iii) Deduce the number of moles of ethanol present at equilibrium in the first test tube.

(1)

(iv) Calculate the number of moles of ethyl ethanoate formed at equilibrium in the first test tube.

(1)

(v) Write an expression for the equilibrium constant, K_c, for the reaction.
Assuming the number of moles of water and ethyl ethanoate present at equilibrium are the same, calculate the equilibrium constant, K_c.

(2)

(vi) Explain why the equilibrium constant for this reaction has no units.

(1)

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(vii) Why, in fact, is the number of moles of water present in the equilibrium mixture greater than the number of moles of ethyl ethanoate?

(1)

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.....

(c) (i) What is the type of reaction that took place in each test tube?

(2)

First test tube

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Second test tube

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*(ii) Comment on the value of the titre for the equilibrium mixture in the second test tube compared to the first test tube.

What characteristic feature of equilibrium reactions is demonstrated by the values of these titres?

(2)

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(iii) State the role of the concentrated hydrochloric acid in the equilibrium reaction.

(1)

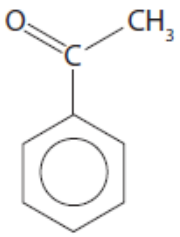
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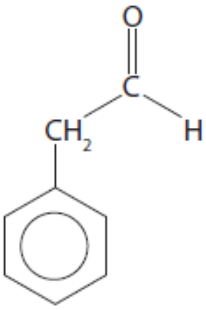
Q29.

Phenylethanone is an ingredient in many types of chewing gum.



One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, CH_3COCl.

Phenylethanone can be distinguished from its structural isomer, phenylethanal, in a number of different ways.



(i) Which would react with phenylethanone but **not** with phenylethanal?

(1)

☒ **A** acidified sodium dichromate(VI)

☒ **B** alkaline iodine solution

☒ **C** Fehling's solution

☒ **D** Tollens' reagent

(ii) Give the steps to show how 2,4-dinitrophenylhydrazine could be used to distinguish between phenylethanone and phenylethanal.

(4)

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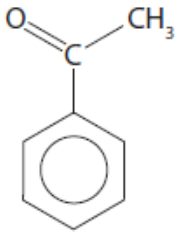
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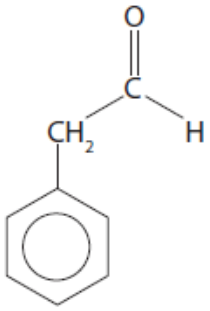
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* (iii) Compare and contrast the high resolution proton NMR spectra of phenylethanone and phenylethanal.

You should use the Data Booklet.



Phenylethanone



Phenylethanal

(6)

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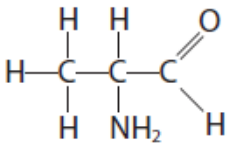
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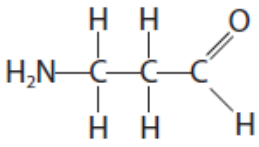
(Total for question = 11 marks)

Q30.

This question is about 2-aminopropanal and 3-aminopropanal.



2-aminopropanal



3-aminopropanal

(a) Explain whether each of the following methods could be used to distinguish between these substances.

Method A Using very accurate mass spectroscopy to measure the relative molecular mass to four decimal places.

Method B Measuring the rotation of the plane of plane-polarised monochromatic light.

Method C Reacting the substances with Fehling's solution.

(3)

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*(b) Describe the high resolution proton NMR spectra of 2-aminopropanal and 3-aminopropanal. Explain how the spectra can be used to distinguish between these substances.

Use of the Data booklet to determine chemical shifts is not required.

(6)

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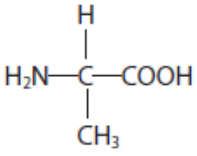
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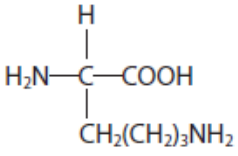
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Q31.

Alanine and lysine are amino acids.



alanine



lysine

Draw the **structure** of the organic product formed when **lysine** reacts with the following reagents:

(3)

aqueous sodium hydroxide, NaOH(aq)

excess dilute hydrochloric acid, HCl(aq)

methanol, with warming, in the presence of a few drops of concentrated sulfuric acid.

(Total for question = 3 marks)

Q32.

Ethanoic acid and ethanol react together to form the ester ethyl ethanoate, $CH_3COOC_2H_5$, and water.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

(a) (i) Give the expression for K_c.

(1)

(ii) An equilibrium was reached when the amounts of substances shown in the table below were used.

Complete the table to show the amounts of each substance present at equilibrium.

(2)

Component	$CH_3COOH(l)$	$CH_3CH_2OH(l)$	$CH_3COOCH_2CH_3(l)$	$H_2O(l)$
Initial amount / mol	0.40	0.30	0.00	0.15
Equilibrium amount / mol	0.20			

(iii) Explain why K_c for this reaction has no units.

(1)

.....

.....

(iv) Calculate the numerical value of K_c.

(1)

(b) The esterification reaction above was carried out in the presence of hydrochloric acid as the catalyst.

State the effect on the equilibrium position and the rate of attainment of equilibrium if the concentration of the acid catalyst were to be increased.

(2)

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(c) (i) Identify which bonds are broken and which bonds are made in the esterification reaction.

(2)

Bonds broken:

Bonds made:

(ii) Explain why ΔH for this reaction is not **exactly** zero.
(A calculation is not required.)

(1)

.....

.....

(d) (i) State the relationship between ΔS_{total} and the equilibrium constant, K, of a reaction.

(1)

*(ii) Use entropy considerations and your answer to (d)(i) to predict any effect of an increase in temperature on the value of the equilibrium constant of a reaction for which ΔH is zero. Assume that ΔS_{system} does not change with temperature.

(3)

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(e) An alternative method for preparing ethyl ethanoate is to react ethanoyl chloride with ethanol.

(i) Give the equation for the reaction.

(1)

(ii) Draw the **skeletal** formula of ethyl ethanoate.

(1)

(iii) Ethanoyl chloride also reacts with concentrated ammonia. Draw the **displayed** formula of the organic product of this reaction.

(1)

(f) (i) Complete the equation below for the alkaline hydrolysis of ethyl ethanoate using sodium hydroxide. State symbols are **not** required.

(1)

$CH_3COOCH_2CH_3 + NaOH \rightarrow$

(ii) Explain why the reaction in (f)(i) gives a better yield of the alcohol compared with acid hydrolysis of the ethyl ethanoate.

(1)

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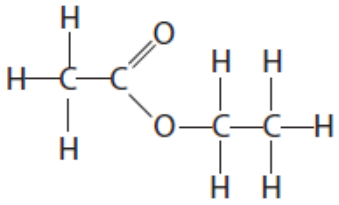
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(Total for question = 19 marks)

Q33.

Ethyl ethanoate is an ester.



Ethyl ethanoate can also be formed by reacting ethanol with ethanoyl chloride, CH_3COCl.

Identify **three** differences in the esterification reaction when ethanoyl chloride is used instead of ethanoic acid.

(3)

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(Total for question = 3 marks)

Q34.

This question is about carboxylic acids and their derivatives.

(a) Which method can be used to produce a carboxylic acid using only the reactants shown?

(1)

☒ **A** hydrolysis of ethyl ethanoate with sodium hydroxide solution

☒ **B** hydrolysis of butanenitrile with dilute hydrochloric acid

☒ **C** reaction of butanoyl chloride with concentrated ammonia

☒ **D** reaction of but-2-ene with acidified potassium manganate(VII)

(b) Which of these reagents can be used to make the ester, propyl ethanoate, in a single step reaction?

(1)

☒ **A** CH_3CH_2CHO and CH_3CH_2OH

☒ **B** CH_3CH_2COCl and CH_3CH_2OH

☒ **C** CH_3CHO and $CH_3CH_2CH_2OH$

☒ **D** CH_3COCl and $CH_3CH_2CH_2OH$

(c) Gas chromatography is used in conjunction with mass spectrometry to analyse esters found in drinks.

State the purpose of each technique.

(i) Gas chromatography

(1)

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(ii) Mass spectrometry

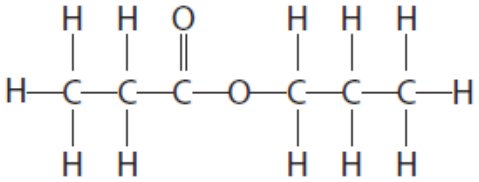
(1)

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Q35.

This question is about esters with the molecular formula $C_6H_{12}O_2$.

Propyl propanoate has the structure shown.



Devise a synthetic pathway to prepare propyl propanoate starting with 1-bromopropane as the **only** organic compound.

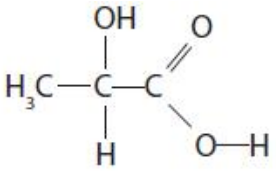
Include the reagents for each step in the synthesis, and the names or structures of the intermediate compounds.

(5)

(Total for question = 5 marks)

Q36.

Ethanal, CH_3CHO, can be converted by a two-step synthesis into 2-hydroxypropanoic acid.



2-hydroxypropanoic acid

The reagents and conditions are

	1st step	2nd step
☒ **A**	$Na_2Cr_2O_7$ and dilute H_2SO_4, heat under reflux	NaOH(aq), heat under reflux
☒ **B**	Cl_2, UV light	NaOH(aq), heat under reflux
☒ **C**	$LiAlH_4$ in dry ether	CO_2, room temperature
☒ **D**	HCN, in presence of KCN(aq)	dilute HCl(aq), heat under reflux

(Total for question = 1 mark)

Q37.

Ethanoic acid, CH_3COOH, can be converted into ethanoyl chloride, CH_3COCl, by the action of

☒ **A** phosphorus(V) chloride.

☒ **B** chlorine.

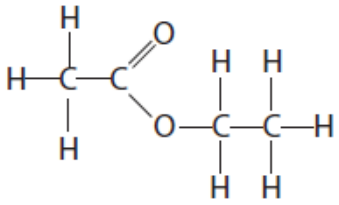
☒ **C** dilute hydrochloric acid.

☒ **D** concentrated hydrochloric acid.

(Total for question = 1 mark)

Q38.

Ethyl ethanoate is an ester.



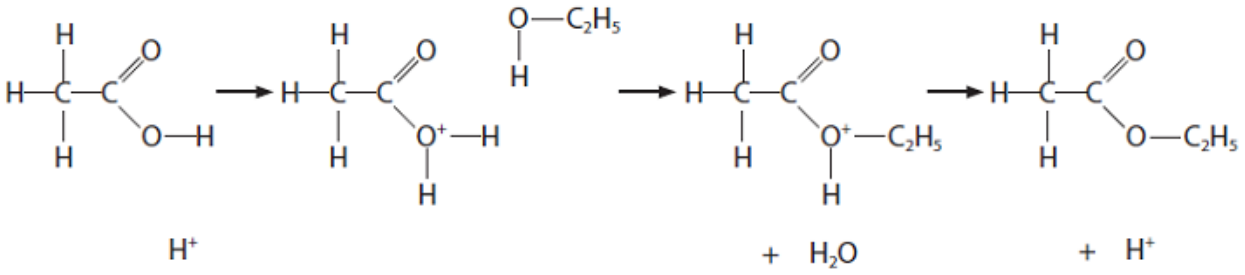
One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

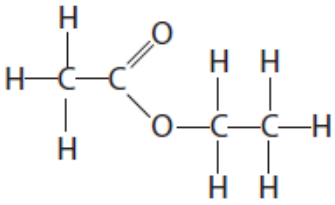
An incomplete simplified mechanism for this reaction is shown.

(i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(4)



(ii) In an experiment, the oxygen atom in ethanol is replaced by the oxygen-18 isotope, ^{18}O.
The products of the esterification are


and H—O—H

Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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(iii) Calculate the standard molar entropy of ethyl ethanoate using your knowledge of Gibbs free energy, ΔG,
and the data in the table.

Include sign and units in your answer.

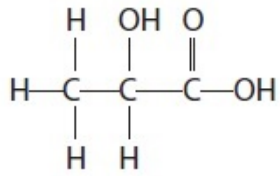
Use $\Delta G = -RT \ln K$ and other appropriate equations.

Quantity	Value
Gas constant, R	8.31 J mol^{-1} K^{-1}
Temperature, T	298 K
Equilibrium constant of esterification reaction, K	4.0
Enthalpy change of esterification reaction, ΔH	–6.0 kJ mol^{-1}
Standard molar entropy of ethanoic acid, $S^{\ominus}$	159.8 J K^{-1} mol^{-1}
Standard molar entropy of ethanol, $S^{\ominus}$	160.7 J K^{-1} mol^{-1}
Standard molar entropy of water, $S^{\ominus}$	69.9 J $K^{-1}mol^{-1}$

(6)

(Total for question = 12 marks)

Q39. 2-hydroxypropanoic acid, lactic acid, is a chiral molecule which is found in muscles and in sour milk. The 2-hydroxypropanoic acid formed in muscles is optically active but that in sour milk is not.



2-hydroxypropanoic acid

(a) (i) Explain the term **chiral**, stating the feature of 2-hydroxypropanoic acid that makes it chiral. Label this feature on the formula above.

(3)

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(ii) What is the difference between the 2-hydroxypropanoic acid formed in muscles and that found in sour milk which gives rise to the difference in optical activity?

(2)

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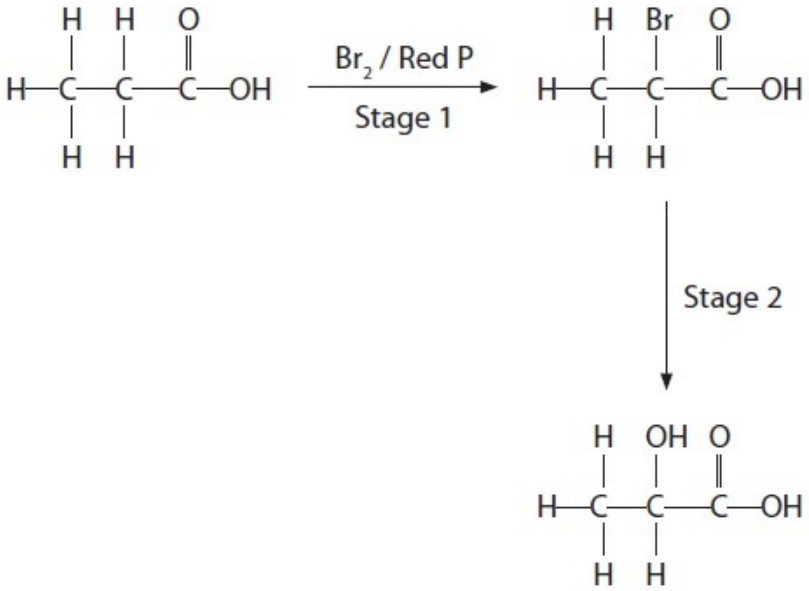
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(b) 2-hydroxypropanoic acid may be prepared in the laboratory from propanoic acid in a two-stage sequence in which 2-bromopropanoic acid is formed as an intermediate:



(i) Stage 2 of this sequence was carried out in two steps. Identify the reagent required for each step in Stage 2.

(2)

First step

.....

Second step

.....

(ii) When an optically active isomer of 2-bromopropanoic acid is used in Stage 2, the resulting 2 hydroxypropanoic acid is also optically active. State and explain what this indicates about the mechanism of the first reaction in Stage 2.

(3)

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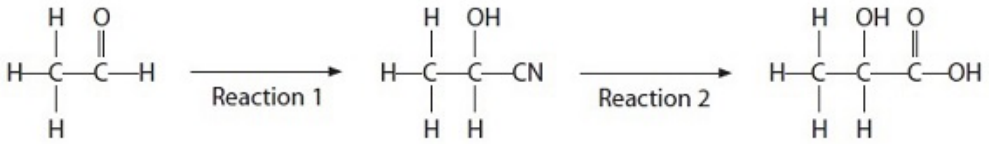
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(c) 2-hydroxypropanoic acid may also be prepared from ethanal in the following sequence:



(i) Name the mechanism and type of reaction occurring in Reaction 1.

(2)

.....

(ii) Identify the attacking species in Reaction 1.

(1)

.....

(iii) Give the first step of the mechanism of Reaction 1, showing the formation of the intermediate.

(2)

*(iv) Explain, by referring to the mechanism in (c)(iii), why the 2-hydroxypropanoic acid formed from ethanal shows no optical activity.

(3)

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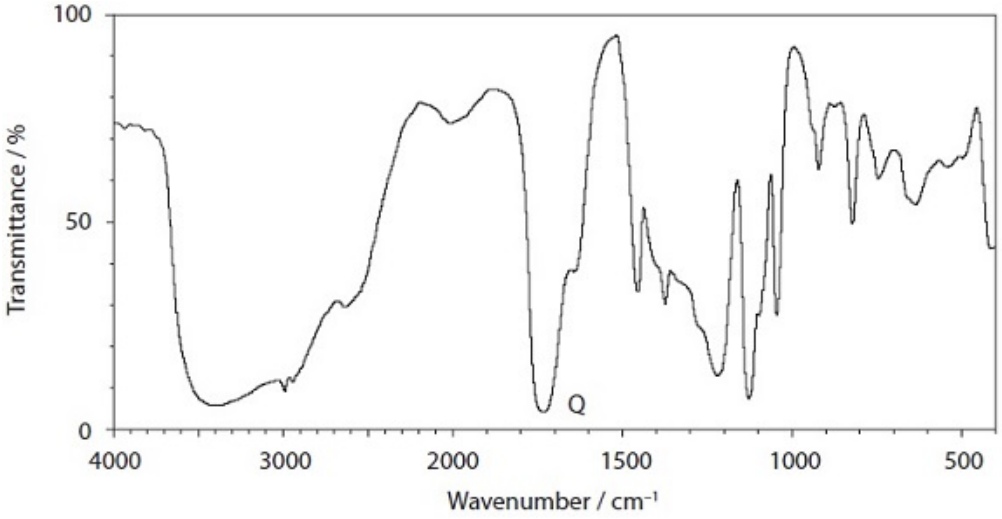
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(d) The infrared spectrum of 2-hydroxypropanoic acid is shown below.



(i) Give the wavenumber of the peak that is present in the infrared spectrum of 2-hydroxypropanoic acid but will not be present in the infrared spectrum of ethanal, identifying the group most likely to be responsible for this peak. Use the data on pages 5 and 6 of the data booklet.

(1)

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*(ii) Identify the bond responsible for absorption peak Q in the spectrum. By considering the wavenumber of this peak, and the data on pages 5 and 6 of the data booklet, explain whether this peak **alone** can be used to distinguish between ethanal and 2-hydroxypropanoic acid.

(3)

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(e) Ethanal and 2-hydroxypropanoic acid can be distinguished by the use of chemical tests. Give two suitable tests **not** involving indicators. For each test, state the observation associated with a positive result.

(4)

Test which is positive for ethanal but not for 2-hydroxypropanoic acid.

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Test which is positive for 2-hydroxypropanoic acid but not for ethanal.

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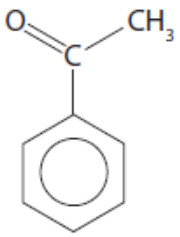
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(Total for Question = 26 marks)

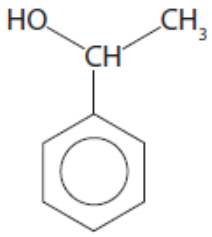
Q40.

Phenylethanone is an ingredient in many types of chewing gum.



One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, CH_3COCl.

The compound 1-phenylethanol can be formed from phenylethanone.



Give the reagent and conditions that would be used to form 1-phenylethanol.

(2)

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(Total for question = 2 marks)

Q41.

The table shows the formulae of three different halogenoalkanes and the optical activity of the products of their reaction with hydroxide ions in aqueous solution.

Reaction	Halogenoalkane reacting with hydroxide ions	Optical activity of product mixture
1	CH_3Cl	none
2	$CH_3CHBrCH_2CH_3$	significant
3	$CH_3CH_2CH_2C(Br)(CH_3)CH_2CH_3$	no significant activity

(a) Draw the mechanism for reaction **1**.

(4)

(b) The halogenoalkane in reaction **2** is 2-bromobutane.

(i) Name the halogenoalkane in reaction **3**.

(1)

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*(ii) Both halogenoalkanes used in reaction **2** and reaction **3** were a single optical isomer.

Explain the optical activity of the product mixture for reaction **2** and reaction **3**, in terms of the reaction mechanism.

(6)

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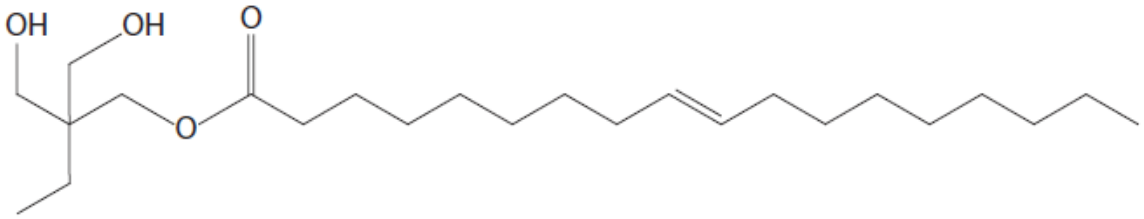
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Q42.

Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.



compound **X**

The effectiveness of this synthetic oil is much reduced if it is contaminated with water.

Give, in terms of a chemical reaction, a possible reason for this.

(1)

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(Total for question = 1 mark)

Q43.

Cinnamon is a spice that is extracted from the bark of the cinnamon tree.

It is extracted by crushing the soft bark with water, and then steam distilling the mixture to produce cinnamon oil.

(b) Compound **Q** is the main component of cinnamon oil. Some chemical tests are carried out to try to find the structure of **Q**.

The results of each test are given in parts (i) to (iii).

Deduce from the results of each test what functional group may be present in **Q**.

(i) **Q** decolourises both bromine water and acidified potassium manganate(VII).

(1)

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(ii) **Q** gives a yellow precipitate with 2,4-dinitrophenylhydrazine.

(1)

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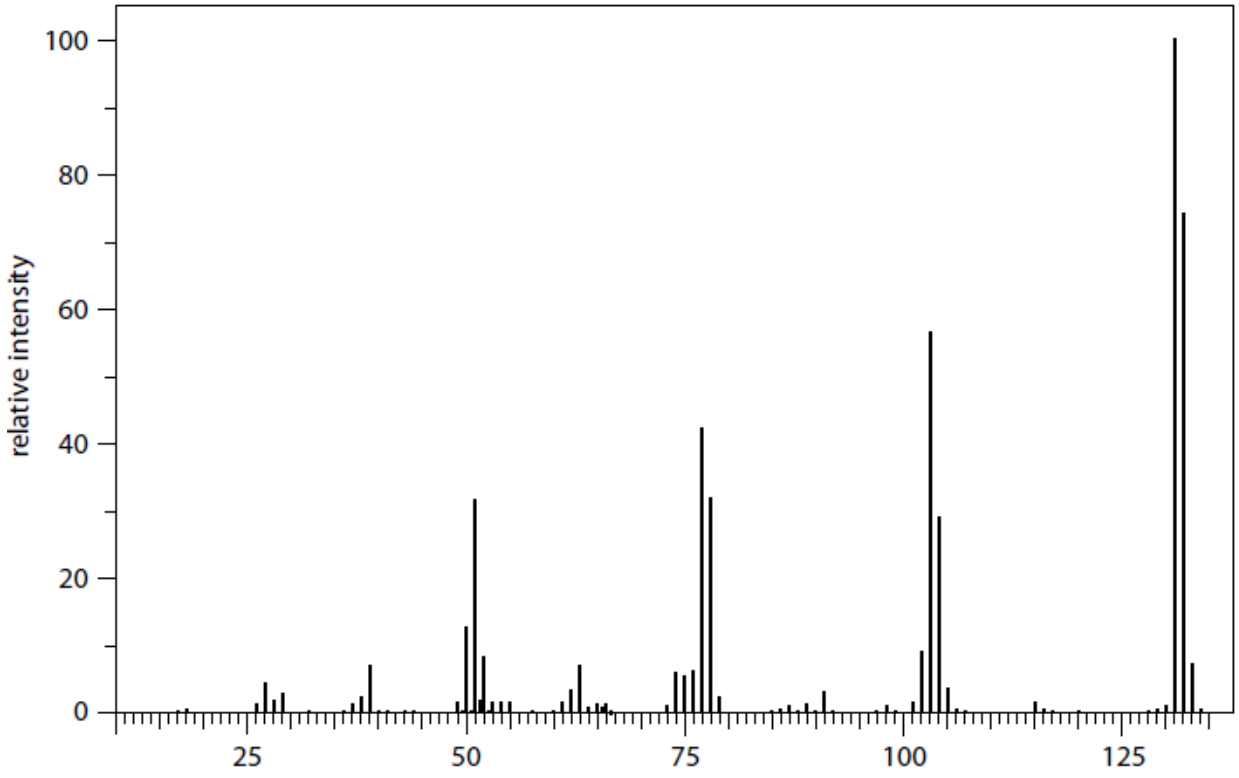
(iii) **Q** forms a red precipitate when boiled with either Benedict's or Fehling's solution.

(1)

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.....

(c) **Q** has the empirical formula C_9H_8O and its mass spectrum is shown.



(i) Predict the identity of the fragment ions causing the peaks at 77 and 103.

(2)

m/z	formula of fragment ion
77	
103	

(ii) Deduce **two** possible displayed formulae for **Q**.

(2)

(iii) The peak at m/z = 132 in the mass spectrum of **Q** is the molecular ion peak. The mass spectrum also shows a peak at m/z = 133.

Give a reason why the peak at m/z = 133 occurs.

(1)

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Q44.

A compound, **Q**, gives an orange precipitate with 2, 4-dinitrophenylhydrazine.
Compound **Q** is resistant to oxidation.
On reduction, **Q** gives a product made up of a pair of optical isomers.

Which of the following compounds could be compound **Q**?

A $CH_3CH_2CH_2COCH_3$

B $CH_3CH{=}CHCH(OH)CH_3$

C $CH_3CH_2CH_2CH_2CHO$

D $CH_3CH_2COCH_2CH_3$

(Total for question = 1 mark)

Q45.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

This question is about the identification of some organic compounds.

The skeletal formulae of four organic compounds are shown.

Q1.

A compound, **Q**, gives an orange precipitate with 2, 4-dinitrophenylhydrazine.
Compound **Q** is resistant to oxidation.
On reduction, **Q** gives a product made up of a pair of optical isomers.

Which of the following compounds could be compound **Q**?

A $CH_3CH_2CH_2COCH_3$

B $CH_3CH{=}CHCH(OH)CH_3$

C $CH_3CH_2CH_2CH_2CHO$

D $CH_3CH_2COCH_2CH_3$

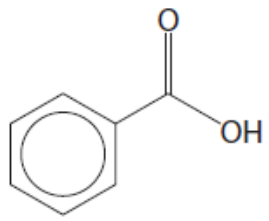
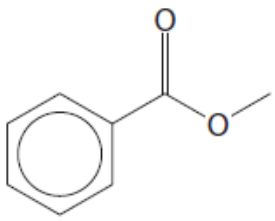
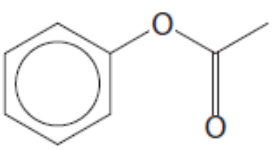
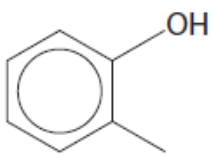
(Total for question = 1 mark)

Q2.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

This question is about the identification of some organic compounds.

The skeletal formulae of four organic compounds are shown.

Compound **P** 	Compound **Q** 
Compound **R** 	Compound **S** 

(i) Which of these compounds can be hydrolysed to form methanol as one of the products?

(1)

☒ **A** Compound P

☒ **B** Compound Q

☒ **C** Compound R

☒ **D** Compound S

(ii) Which of these compounds produces carbon dioxide when it reacts with aqueous sodium hydrogencarbonate?

(1)

☒ **A** Compound P

☒ **B** Compound Q

☒ **C** Compound R

☒ **D** Compound S

(Total for question = 2 marks)

Q3.

This question is about the identification of some organic compounds.

Compound **T**, $C_4H_{10}O$, is oxidised by acidified potassium dichromate(VI) to form compound **U**, C_4H_8O.

U gives an orange precipitate with 2,4-dinitrophenylhydrazine (Brady's reagent) but does **not** give a red precipitate when heated with Fehling's solution.

T reacts with ethanoyl chloride to form compound **V**, $C_6H_{12}O_2$.

Deduce the structures of compounds **T**, **U** and **V**. Justify your answers.

(6)

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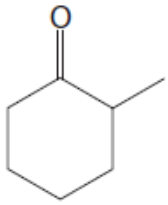
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(Total for question = 6 marks)

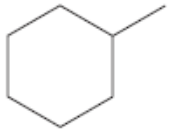
Q4.

Which of the following compounds is **not** chiral?

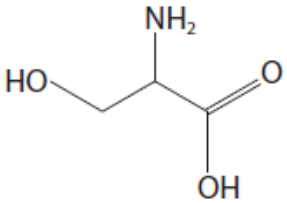
☒ **A**



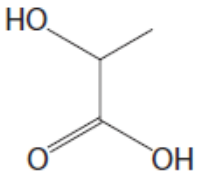
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q5.

Consider the four compounds shown below.

A CH_3COOCH_3

B CH_3COOH

C $CH_3CONHCH_2CH_3$

D CH_3COCl

Which of these compounds

(a) will react most vigorously with water?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) forms methanol when refluxed with aqueous sodium hydroxide?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) has at least one triplet in its high resolution proton nmr spectrum?

(1)

☒ **A**

☒ **B**

☒ **C**

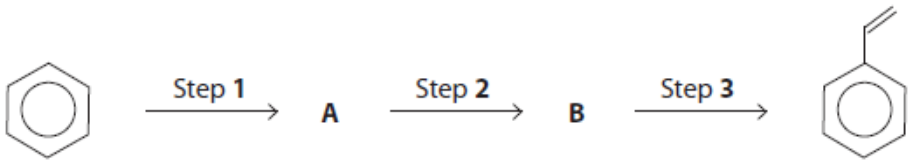
☒ **D**

(Total for question = 3 marks)

Q6.

Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from

benzene in a three-step synthesis.



Some of the following compounds can be used to make phenylethene from benzene.

Aluminium chloride	Chloroethane	Ethanal	Ethanol
Ethanoic acid	Ethanoyl chloride	Ethene	Ether
Hydrochloric acid, concentrated	Lithium tetrahydridoaluminate(III)	Phosphoric acid, concentrated	Sulfuric acid, concentrated

Selecting **only** from these compounds, devise a synthetic pathway for converting benzene into phenylethene, clearly identifying compounds **A** and **B** and stating the appropriate conditions for each step.

(5)

(Total for question = 5 marks)

Q7.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.

Methyl cinnamate undergoes an addition reaction in the dark with bromine.

(i) Draw the mechanism for the reaction between methyl cinnamate and bromine, Br_2.

Include curly arrows, and relevant lone pairs and dipoles.

(4)

(ii) Deduce the number of optical isomers of the addition product that can exist.

(1)

☐ **A** 2

☐ **B** 3

☐ **C** 4

☒ **D** 8

(iii) When plane-polarised light is passed through an optical isomer, the plane of polarisation is

(1)

☒ **A** diffracted

☒ **B** reflected

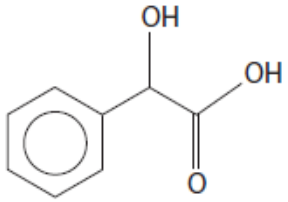
☒ **C** refracted

☒ **D** rotated

(Total for question = 6 marks)

Q8.

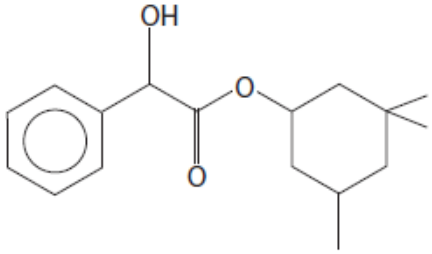
The compound mandelic acid is used in cosmetic skin peels.



(a) Draw a reaction scheme, including reagents, to show how mandelic acid can be synthesised in **two** steps from benzenecarbaldehyde (benzaldehyde), C_6H_5CHO.

(3)

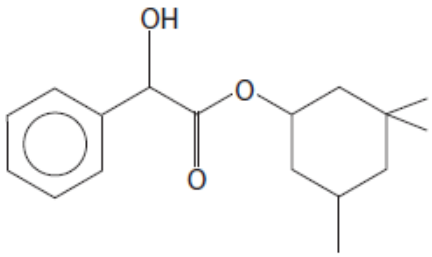
(b) The compound cyclandelate is used to treat a condition called Raynauld's disease, which affects blood flow to the body's extremities, such as fingers and toes. The structure of cyclandelate is



Draw the structure of a compound that could react with mandelic acid to form cyclandelate. Name the reaction type that occurs.

(2)

(c) A derivative of mandelic acid, 4-nitromandelic acid, is used as a solid phase support in the synthesis of peptides.



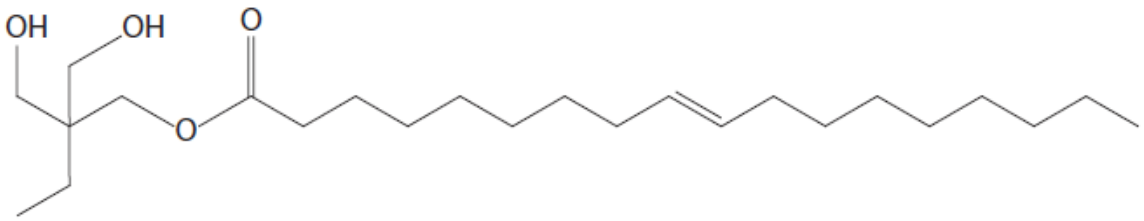
Draw the mechanism for the formation of 4-nitromandelic acid from mandelic acid.

(4)

(Total for question = 9 marks)

Q9.

Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.



compound **X**

Name the **three** functional groups present in compound **X**.

(2)

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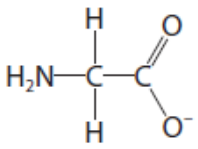
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(Total for question = 2 marks)

Q10.

Some organic compounds contain metals.

Glycinate ions are formed from the amino acid glycine.



glycinate ion

(i) Explain the effect, if any, of an aqueous solution containing glycinate ions on

plane-polarised monochromatic light.

(2)

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(ii) A hot aqueous solution of glycine is added to a hot solution of copper(II) ethanoate.

When the mixture is cooled, crystals of copper(II) glycinate are formed.

Write the equation for this reaction.
State symbols are not required.

(2)

(iii) In an experiment, the crystals are filtered, weighed and the percentage yield calculated.

Student **1** obtained a yield of 102.6%.

Student **2** obtained a yield of 56.4%.

The expected yield is 82% and the students carried out the calculation correctly.

Discuss possible reasons for the yields obtained by these students.

(4)

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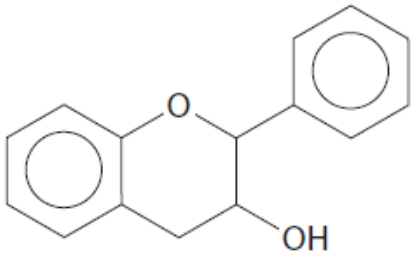
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(Total for question = 8 marks)

Q11.

The compound flavan-3-ol is found in tea, fruit and wine.



*A sample of flavan-3-ol extracted from wine contained some ethanol. The sample was left in a flask, open to the air for several days. The contents were then analysed to identify any new compounds formed. Several new compounds were found to be present, including some with a distinctive fruity smell.

Identify **four** new organic compounds that could form under these conditions by considering the chemistry of alcohols. Justify your answers. Include the structure of two compounds formed from flavan-3-ol, one of which has a fruity smell.

(6)

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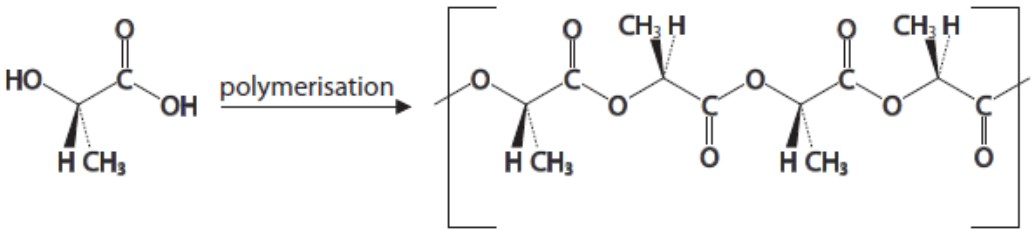
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(Total for question = 6 marks)

Q12.

This question is about lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)COOH$.
Lactic acid is used to make biodegradable polymers.

Polymerisation of lactic acid forms poly(lactic acid) as shown in the diagram.



(i) State the type of polymerisation occurring in this reaction.

(1)

.....

(ii) **On the diagram**, draw a circle around the repeat unit of the polymer.

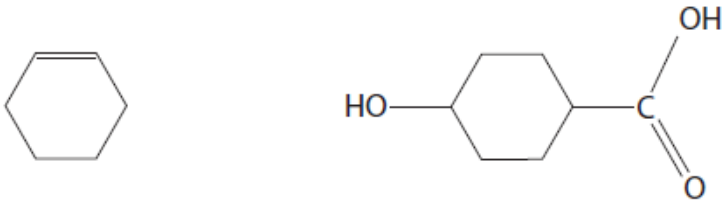
(1)

(Total for question = 2 marks)

Q13.

* This question is about polymers.

Compare and contrast how each of these monomers forms a polymer.



cyclohexene

4-hydroxycyclohexanecarboxylic acid

Include equations, showing the formation of a single repeat unit for each polymer.

(6)

(Total for question = 6 marks)

Q14.

The chemistry of organic compounds containing a chlorine atom is affected by the presence of other groups.

Consider the reaction of ammonia, NH_3, with $CH_3CH_2CH_2Cl$ and with CH_3CH_2COCl.

Predict the mechanism for the reaction of CH_3CH_2COCl with ammonia. Include curly arrows and relevant lone pairs.

(3)

(Total for question = 3 marks)

Q15.

This question is about four organic compounds, each containing two carbon atoms.

A CH_3CH_2OH

B CH_3CHO

C CH_3COOH

D CH_3COCl

(a) Which is oxidized by ammoniacal silver nitrate?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which has the highest boiling temperature?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) 0.01 mol of each compound is heated separately with excess acidified sodium dichromate(VI).

Which compound reduces the largest amount of sodium dichromate(VI)?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) 0.01 mol of each compound is added separately to identical volumes of water. Which solution would have the lowest pH?

(1)

☒ **A**

☒ **B**

☒ **C**

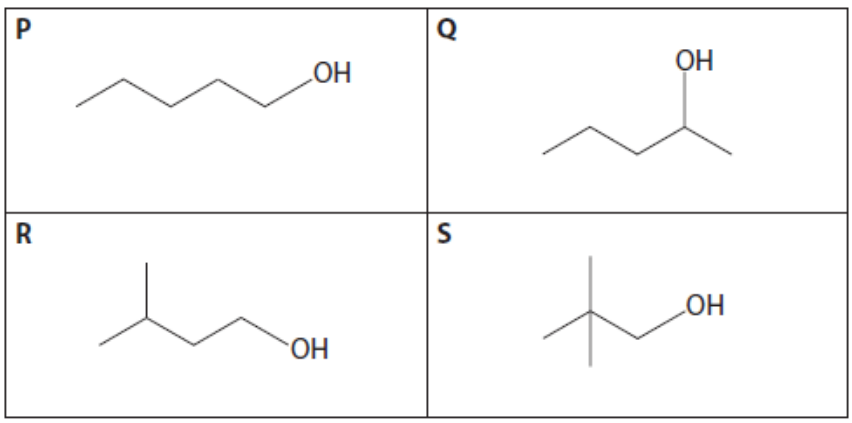
☒ **D**

(Total for question = 4 marks)

Q16.

This question is about alcohols.

The skeletal formulae of four alcohols with molecular formula $C_5H_{12}O$ are shown.



(i) Which of the alcohols has a chiral centre?

(1)

☒ **A** alcohol **P**

☒ **B** alcohol **Q**

☒ **C** alcohol **R**

☒ **D** alcohol **S**

(ii) Which of the alcohols are classified as primary?

(1)

☒ **A** alcohol **P** only

☒ **B** alcohols **P** and **R** only

☒ **C** alcohols **P**, **R** and **S** only

☒ **D** alcohols **P**, **Q**, **R** and **S**

(iii) Which of the alcohols can be oxidised to form 3-methylbutanoic acid?

(1)

☒ **A** alcohol **P**

☒ **B** alcohol **Q**

☒ **C** alcohol **R**

☒ **D** alcohol **S**

Q17.

Four organic compounds are:

A CH_3OH

B HCHO

C HCOOH

D $HCOOCH_3$

(a) Which of these compounds has a fruity smell?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) 0.01 mol of each compound is added separately to identical volumes of water.
Which solution would have the lowest pH?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) 0.01 mol of each compound is heated separately with excess acidified sodium dichromate(VI) solution. Which compound reduces the largest amount of sodium dichromate(VI)?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) Which compound has the highest boiling temperature?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(e) Which of these compounds can be oxidized by ammoniacal silver nitrate?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 5 marks)

Q18.

When one optically active isomer of 3-chloro-3-methylhexane reacts with hydroxide ions to form 3-methylhexan-3-ol, a racemic mixture forms because

☒ **A** 3-chloro-3-methylhexane forms a carbocation intermediate.

☒ **B** the reaction is a nucleophilic substitution.

☒ **C** 3-chloro-3-methylhexane forms a five-bonded transition state.

☒ **D** 3-methylhexan-3-ol contains a chiral carbon.

(Total for question = 1 mark)

Q19.

This question is about extracting benzoic acid from a mixture of benzoic acid, C_6H_5COOH, and phenol, C_6H_5OH.

The following steps were carried out.

Step **1** A suitable mass of the mixture was placed in a separating funnel and some ether added. The funnel was shaken to dissolve the mixture.

Step **2** Aqueous sodium hydrogencarbonate was added to the separating funnel, and the contents shaken.

Step **3** Once the reaction was complete, the two layers were allowed to separate.

Step **4** The lower aqueous layer was removed and placed in a beaker.

Step **5** The ether layer in the separating funnel was washed with deionised water and the washings added to the beaker.

Step **6** Hydrochloric acid was added to the aqueous solution in the beaker to precipitate the benzoic acid.

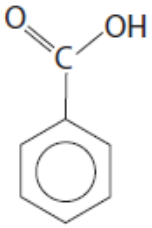
Step **7** The impure benzoic acid was filtered under reduced pressure.

Step **8** The impure benzoic acid was purified by recrystallisation.

Step **9** The melting temperature of the purified benzoic acid was measured and compared with the literature value of 122°C.

Complete the equation for the reaction between benzoic acid and sodium hydrogencarbonate.

(2)



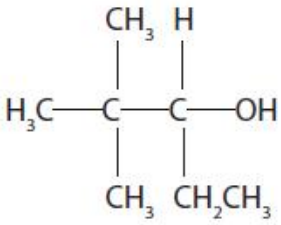
+ ..... → ..... + ... + ...

(Total for question = 2 marks)

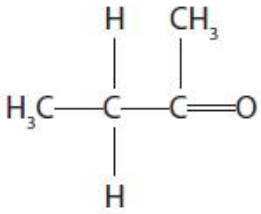
Q20.

Questions (a) to (d) concern the following organic compounds.

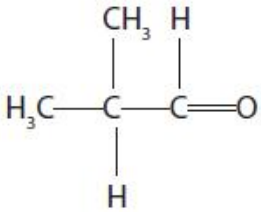
Compound A



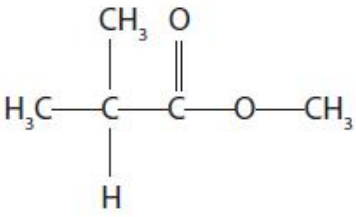
Compound B



Compound C



Compound D



Select from **A** to **D** the compound that

(a) forms iodoform with iodine in the presence of alkali.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(b) is chiral.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(c) reacts with Tollens' reagent.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(d) can be oxidized to form a ketone.

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for question = 4 marks)

Q21.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

This question is about some reactions of alcohols.

(i) Which alcohol **cannot** be oxidised by acidified potassium dichromate(VI)?

(1)

☐ **A** hexan-2-ol

☐ **B** 2-methylpentan-2-ol

☐ **C** hexan-3-ol

☐ **D** 2-methylpentan-3-ol

(ii) Which alcohol reacts with iodine in the presence of alkali to form a yellow solid?

(1)

☐ **A** hexan-2-ol

☐ **B** 2-methylpentan-2-ol

☐ **C** hexan-3-ol

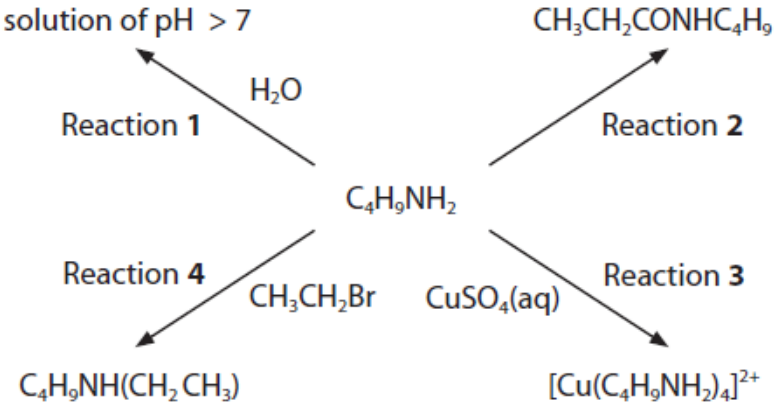
☐ **D** 2-methylpentan-3-ol

(Total for question = 2 marks)

Q22.

This question is about the amines butylamine, $C_4H_9NH_2$, and phenylamine, $C_6H_5NH_2$.

The reaction scheme shows some reactions of butylamine, a primary amine.



Give the name and structural formula of the compound needed to react with butylamine in Reaction **2**.

(2)

Name.....

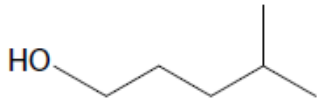
Structural formula.....

(Total for question = 2 marks)

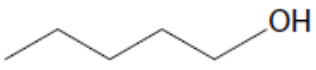
Q23.

The skeletal formulae of four compounds are shown.

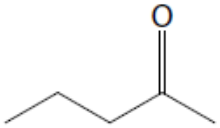
A



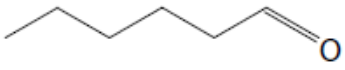
B



C



D



(b) Which compound forms a pale yellow precipitate when reacted with iodine and sodium hydroxide solution?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which compound forms a silver mirror when reacted with Tollens' reagent?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

Q24.

This question is about some carbonyl compounds with the molecular formula $C_5H_{10}O$.

Describe a chemical test, and its result, to distinguish between pentan-2-one, $CH_3CH_2CH_2COCH_3$, and pentan-3-one, $CH_3CH_2COCH_2CH_3$.

(2)

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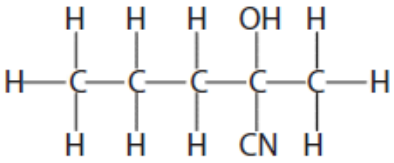
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(Total for question = 2 marks)

Q25.

This question is about some carbonyl compounds with the molecular formula $C_5H_{10}O$.

Pentan-2-one reacts with hydrogen cyanide in the presence of cyanide ions to form 2-hydroxy-2-methylpentanenitrile.



2-hydroxy-2-methylpentanenitrile

(i) Draw the mechanism for the reaction between pentan-2-one and hydrogen cyanide in the presence of cyanide ions.

Include curly arrows and any relevant lone pairs.

(4)

(ii) The product of this reaction, 2-hydroxy-2-methylpentanenitrile, has a chiral centre.
Explain why a racemic mixture of 2-hydroxy-2-methylpentanenitrile is formed in this reaction.

(2)

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(Total for question = 6 marks)

Q26.

This question is about some carbonyl compounds with the molecular formula $C_5H_{10}O$.

* Describe the oxidation and reduction reactions of pentanal and pentan-3-one.

Include the reagents and the structures of the organic products formed in any reactions that

take place.

(6)

(Total for question = 6 marks)

Q27.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

This question is about a dicarboxylic acid **Y** which is present in some citrus fruits.
Y contains only the elements carbon, hydrogen and oxygen.

Which of these is used to convert a dicarboxylic acid into a diol?

☒ **A** $LiAlH_4$ and ether

☒ **B** $KMnO_4$ and H_2SO_4

☒ **C** Sn and HCl

☒ **D** $Na_2Cr_2O_7$ and H_2SO_4

(Total for question = 1 mark)

Q28.

Sodium tetrahydridoborate(III), $NaBH_4$, is used in organic chemistry.
It is an alternative reagent to lithium tetrahydridoaluminate(III) for the reduction of carbonyl compounds.

(i) Draw a dot-and-cross diagram of the BH_4^- ion.

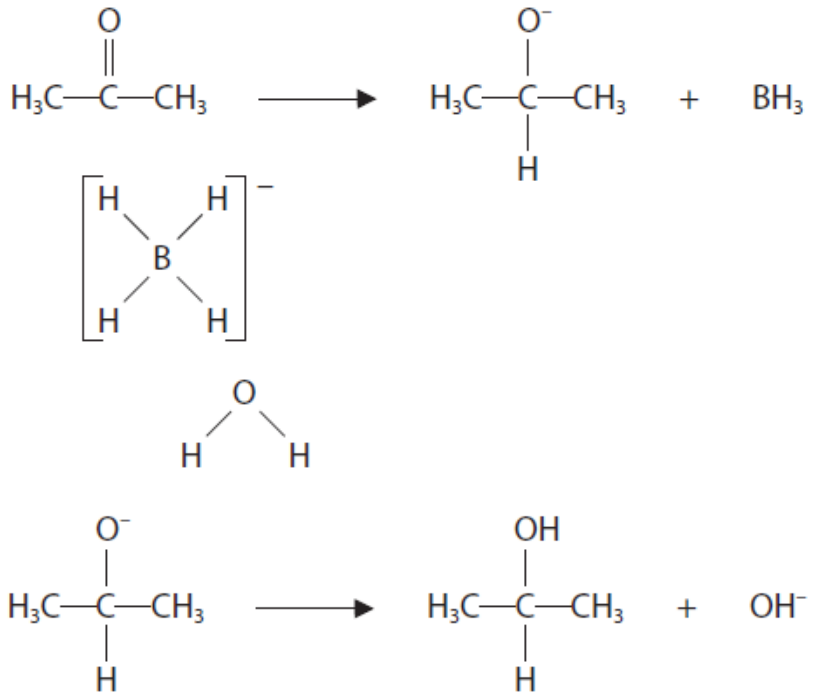
Use crosses (×) for the boron electrons, dots (•) for the hydrogen electrons and triangles (Δ) for the additional electron forming the negative ion.

(1)

(ii) The BH_4^- ions reduce carbonyl compounds to alcohols in aqueous solution.

Complete the mechanism for the reduction of propanone to propan-2-ol by adding curly arrows, and any relevant lone pairs and dipoles.

(4)



(Total for question = 5 marks)

Q29.

Some chemical tests are described below.

A Warm with Fehling's (or Benedict's) solution

B Warm with acidified potassium dichromate(VI) solution

C Add sodium carbonate solution

D Add 2,4-dinitrophenylhydrazine solution

(a) Which test always gives a positive result with carbonyl compounds?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which test would give a positive result with ethane-1,2-diol?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which test would result in effervescence with ethanoic acid?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 3 marks)

Q30.

2-bromobutane can react with aqueous hydroxide ions by an S_N1 mechanism.

Explain why the butan-2-ol produced from a single optical isomer of 2-bromobutane, using this mechanism, is **not** optically active.

(3)

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(Total for question = 3 marks)

Q31.

This question is about extracting benzoic acid from a mixture of benzoic acid, C_6H_5COOH, and phenol, C_6H_5OH.

The following steps were carried out.

Step **1** A suitable mass of the mixture was placed in a separating funnel and some ether added. The funnel was shaken to dissolve the mixture.

Step **2** Aqueous sodium hydrogencarbonate was added to the separating funnel, and the contents shaken.

Step **3** Once the reaction was complete, the two layers were allowed to separate.

Step **4** The lower aqueous layer was removed and placed in a beaker.

Step **5** The ether layer in the separating funnel was washed with deionised water and the washings added to the beaker.

Step **6** Hydrochloric acid was added to the aqueous solution in the beaker to precipitate the benzoic acid.

Step **7** The impure benzoic acid was filtered under reduced pressure.

Step **8** The impure benzoic acid was purified by recrystallisation.

Step **9** The melting temperature of the purified benzoic acid was measured and compared with the literature value of 122 °C.

Benzoic acid can be purified in Step **8** because of its high solubility in hot water and low solubility in cold water.

Calculate the maximum number of benzoic acid molecules that can dissolve in 50.0 cm^3 of cold water if the solubility is 1.70 g per 1000 cm^3.

(3)

(Total for question = 3 marks)

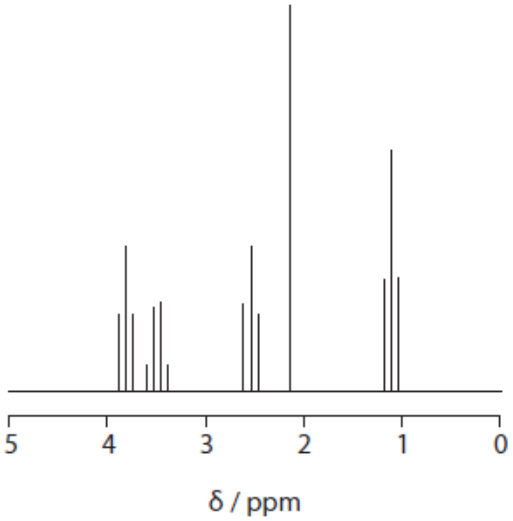
Q32.

This question is about the use of NMR spectroscopy to distinguish between isomers of $C_6H_{12}O_2$.

(i) Draw the structural formulae of the **two** esters with formula $C_6H_{12}O_2$ that each have only **two** peaks, both singlets, in their high resolution **proton** NMR spectra. The relative peak areas are 3:1 for both esters.

(2)

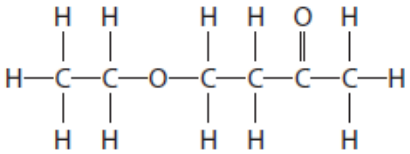
(ii) The high resolution **proton** NMR spectrum of another isomer of $C_6H_{12}O_2$ is shown.



The ratios of the number of protons for the five sets peaks in the spectrum are given in the table.

δ / ppm	3.8	3.5	2.6	2.2	1.2
Ratio of the number of protons	2	2	2	3	3

Show that **all** these data are consistent with the displayed formula shown. Refer to the five chemical shifts and explain **two** of the splitting patterns.



(5)

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(Total for question = 7 marks)

Q33.

This question is about esters with the molecular formula $C_6H_{12}O_2$.

Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed.
It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of
but-1-ene and but-2-ene.

Deduce the structures of **B** and **A**. Justify your structure of **B**.

(3)

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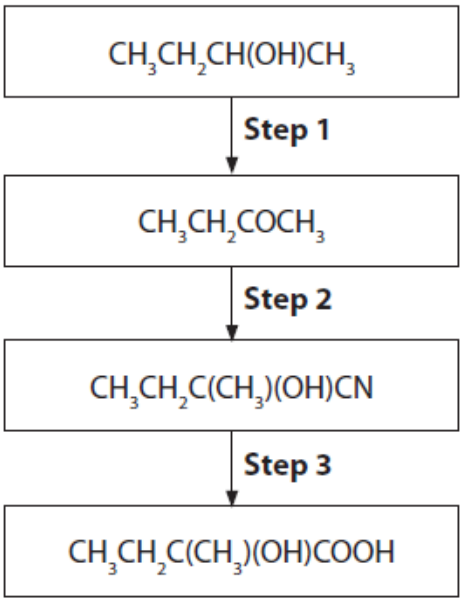
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(Total for question = 3 marks)

Q34.

A flow chart for making 2-hydroxy-2-methylbutanoic acid from butan-2-ol is show below.



(a) (i) Give the reagents and conditions for **Step 1**.

(2)

.....

.....

.....

(ii) Butanone is formed in **Step 1**.

Give a chemical test to identify the carbonyl group and a further test to show the presence of the $H_3C-\overset{\overset{O}{\|}}{C}-$ group.

For both tests, give the observations that you would make.

(4)

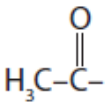
Carbonyl group

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 group

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(b) (i) In **Step 2**, butanone undergoes an addition reaction with HCN in the presence of CN^- ions.

Give the mechanism for this reaction.

(3)

*(ii) By considering the mechanism of the reaction, explain why the addition of hydrogen cyanide to butanone gives a solution which has no effect on the plane of polarization of plane-polarized light.

(3)

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(c) (i) Suggest the type of reaction occurring in **Step 3**.

(1)

.....

(ii) Explain why the presence of the alcoholic hydroxyl group cannot be confirmed in the infrared spectrum of 2-hydroxy-2-methylbutanoic acid.

(1)

.....

.....

(iii) The hydrogen of the alcohol group in 2-hydroxy-2-methylbutanoic acid can be identified by a single peak in the nmr spectrum.

Give the chemical shift you would expect for this peak.

(1)

.....

(iv) Explain why, in high resolution nmr, the peak due to the hydrogens of the 2-methyl group in 2-hydroxy-2-methylbutanoic acid is a singlet.

(1)

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(d) Molecules of 2-hydroxy-2-methylbutanoic acid react together to form a condensation polymer.

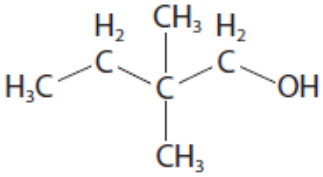
Draw a **displayed** formula for this polymer, showing two repeating units.

(2)

(Total for question = 18 marks)

Q35.

The alcohol 2,2-dimethylbutan-1-ol has the structure



Devise a reaction scheme for a synthesis of this alcohol starting from 2-bromo-2-methylbutane. Include in your answer all reagents and conditions and the structures of any intermediate compounds.

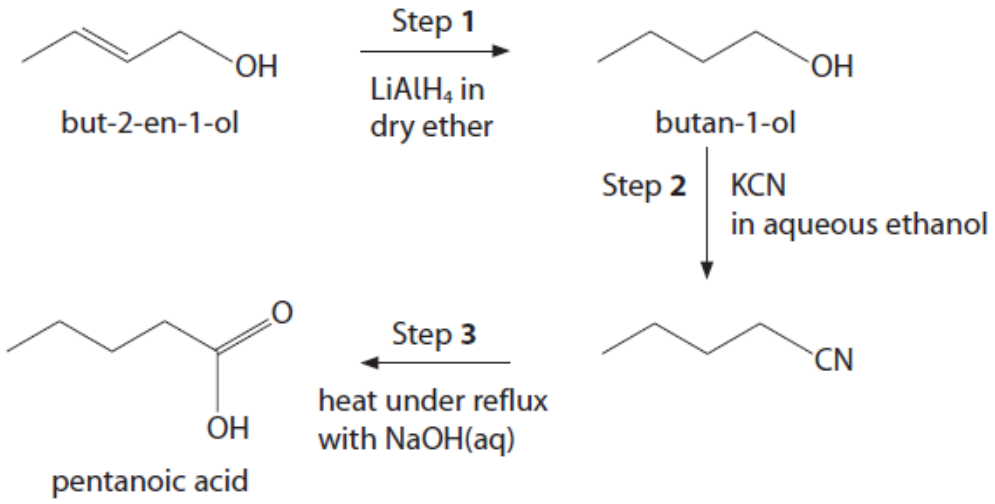
(6)

(Total for question = 6 marks)

Q36.

This question is about the synthesis of organic compounds.

A student suggested the following plan for the synthesis of pentanoic acid from but-2-en-1-ol.



(i) $LiAlH_4$ is a source of hydride ions, H^-.

Give a possible reason why $LiAlH_4$ cannot be used to reduce alkenes.

(1)

.....

.....

.....

(ii) Give a suitable reagent and condition for Step **1**.

(2)

.....

(iii) Step **2** is incorrect because alcohols can only be converted to nitriles via an intermediate compound.

Identify a suitable intermediate compound by name or formula.

(1)

.....

(iv) Step **3** involves the hydrolysis of a nitrile.

Give the additional reagent that should be added after heating under reflux with aqueous sodium hydroxide, to produce
pentanoic acid.

(1)

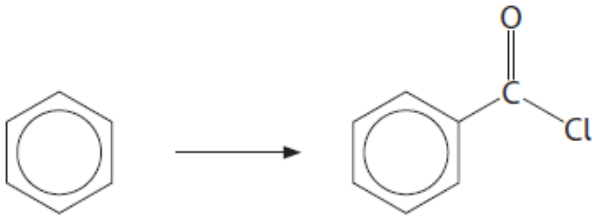
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(Total for question = 5 marks)

Q37.

This question is about the synthesis of organic compounds.

Devise a four-step synthesis, involving the use of a Grignard reagent, to convert benzene into benzoyl chloride.



Include the reagents and conditions for each step in the synthesis and the structures of the intermediates.

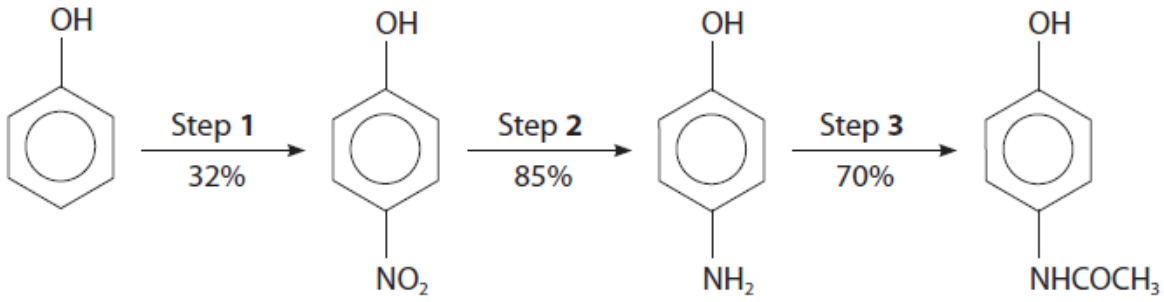
(7)

(Total for question = 7 marks)

Q38.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

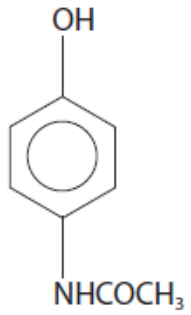
The painkiller paracetamol can be synthesised from phenol in three steps.
The percentage yield for each step is shown.



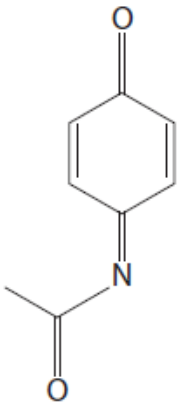
phenol

paracetamol

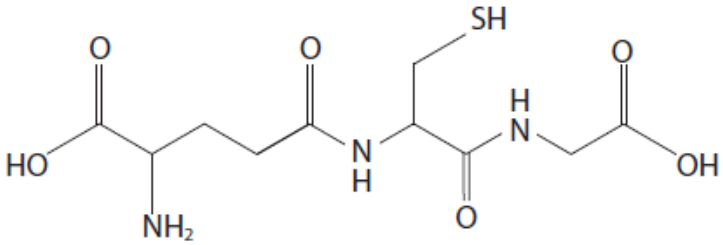
When metabolised in the body, paracetamol forms a toxic compound **Z**.
This is then removed in the liver by a reaction with the tripeptide glutathione.



paracetamol



compound **Z**



glutathione

(i) The conversion of paracetamol to compound **Z** is

(1)

☒ **A** addition

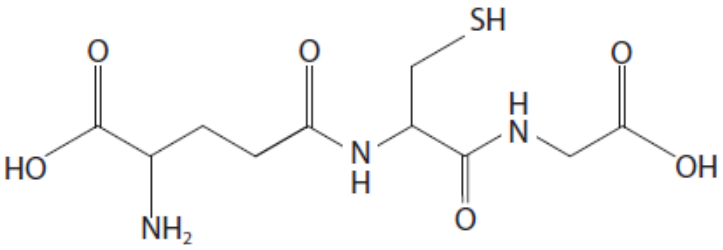
☒ **B** hydrolysis

☒ **C** oxidation

☒ **D** reduction

(ii) Draw a circle around each of the chiral carbon atoms in glutathione.

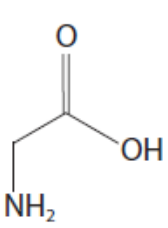
(1)



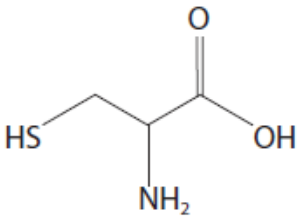
(iii) Glutathione is formed from glycine and two other amino acids.

Which two amino acids combine with glycine to form glutathione?

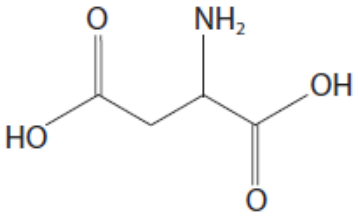
(1)



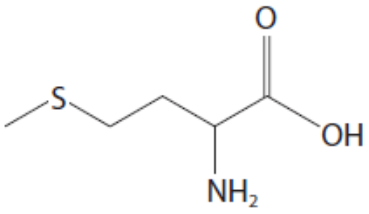
glycine



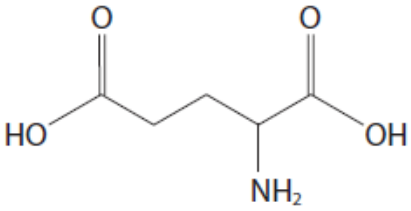
cysteine



aspartic acid



methionine



glutamic acid

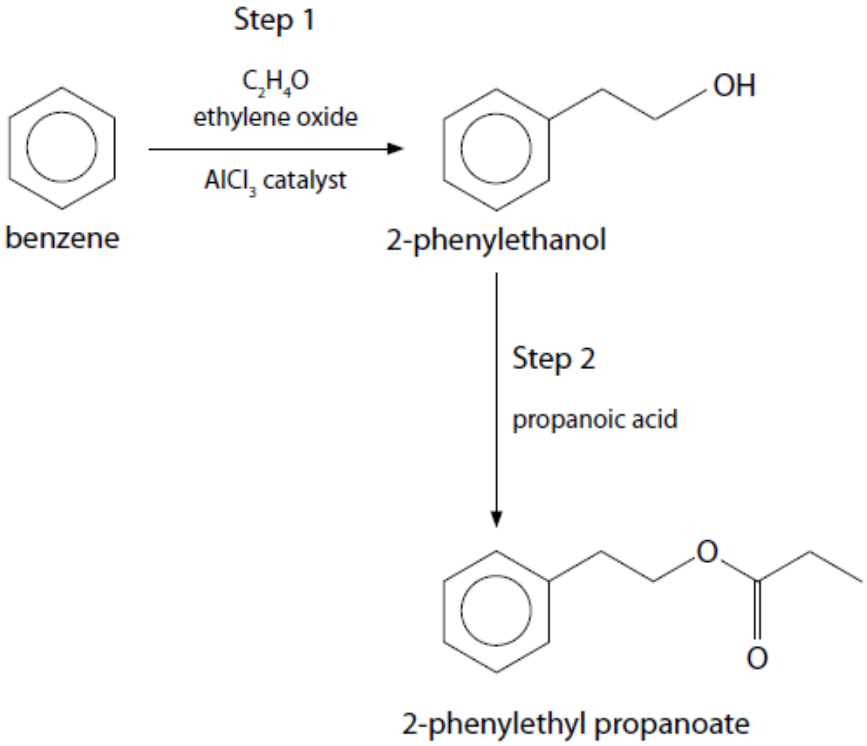
- ☒ **A** aspartic acid and cysteine
- ☒ **B** glutamic acid and cysteine
- ☒ **C** glutamic acid and methionine
- ☒ **D** aspartic acid and methionine

(Total for question = 4 marks)

Q39.

The compound 2-phenylethyl propanoate is a synthetic oil used in some fragrances due to its rose-like aroma.

A possible synthetic route to prepare 2-phenylethyl propanoate is:



(i) The attacking species in Step 1 can be represented as $^{+}CH_2CH_2OAlCl_3^{-}$

What is the mechanism in this step?

(1)

☒ **A** electrophilic substitution

☒ **B** nucleophilic substitution

☒ **C** electrophilic addition

☒ **D** nucleophilic addition

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction to form 2-phenylethanol.

(4)