

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

WHAT'S IN A MEDICINE? (WM)

SCORE

/334

PERCENTAGE

%

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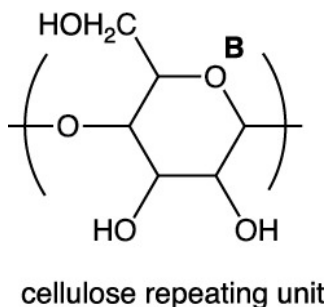
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- 1 Film, used to make motion pictures, consists of a light-sensitive emulsion supported on a 'film base'. The film base is made from a polymer. Most of the polymers were based on cellulose. The repeating unit for cellulose is given below.



- (i) Name the functional group labelled **B** in the structure of cellulose.

----- [1]

- (ii) **Circle** a secondary alcohol group on the structure of cellulose shown above.

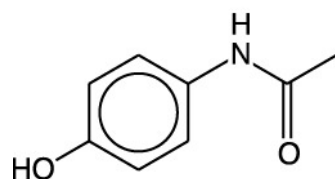
[1]

- (iii) Cellulose is made by condensation reactions of a single monomer.

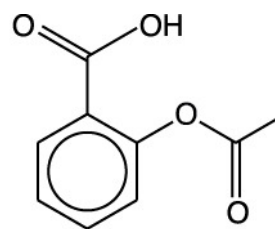
Give the **full** structural formula of the monomer from which cellulose is formed.

[2]

2(a) Disprin Extra is a medicine containing the active compounds C and D.



compound C



compound D

Give **two** chemical tests that will distinguish between compounds C and D.

Choose **one** chemical test that gives a positive result for C and **one** that gives a positive result for D.

Test for C

.....

Observations

.....

Test for D

.....

Observations

.....

[4]

(b) Heating a few Disprin Extra tablets under reflux with hydrochloric acid (aqueous) produces a mixture. Two aromatic compounds can be isolated from the mixture.

(i) Draw structural formula for the two aromatic compounds.

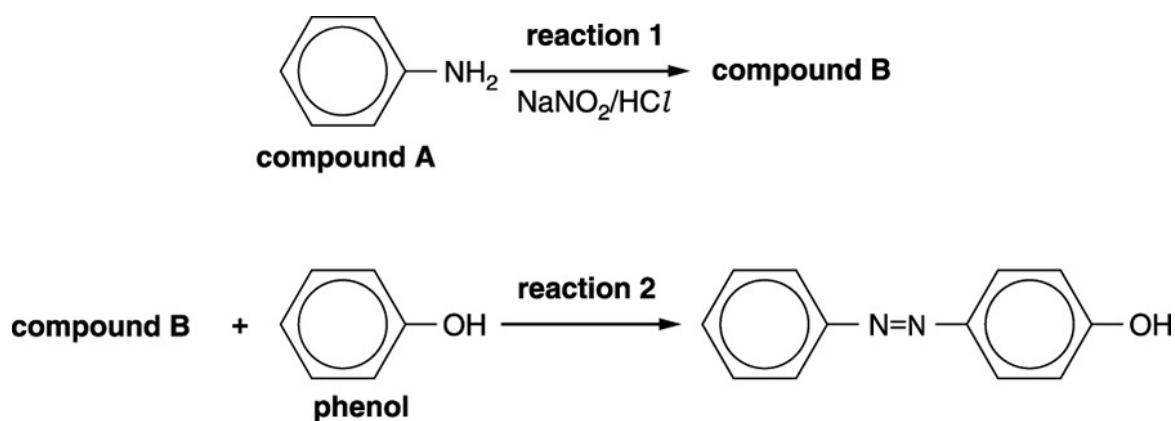
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[2]

(ii) Describe how a student would use thin-layer chromatography to show that a mixture from the hydrolysis of Disprin Extra contains both aromatic compounds.

[6]

3 A reaction scheme for the formation of a simple azo dye is shown below.



(i) Name the functional group in compound **A** other than the benzene ring.

-----[1]

(ii) Name compound **B**.

-----[1]

(iii) Give the name that describes **reaction 2** in the context of dye formation.

-----[1]

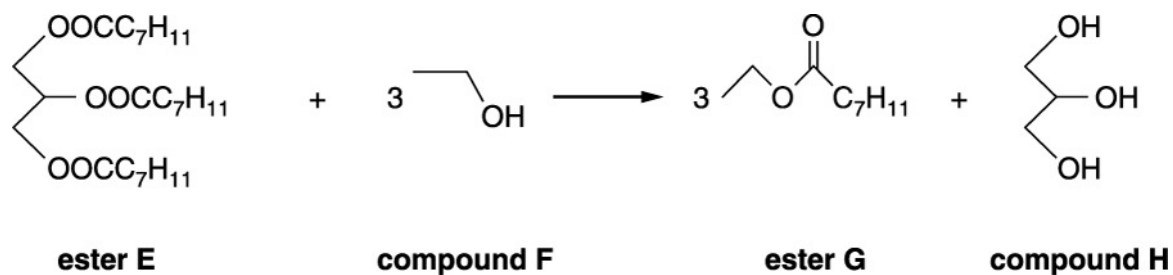
(iv) Phenol is acidic in solution. Carboxylic acids are also acidic but react in a way that phenols do not.

Give details of this acidic reaction of carboxylic acids.

-----[2]

- 4 Trans-esterification reactions are used to make esters from vegetable oils. These esters are suitable for use as biofuels, such as biodiesel.

One trans-esterification reaction is shown below.



- (i) A chemist makes ester **G** in the laboratory by reacting the appropriate acid and the alcohol ROH.

Write an equation for the equilibrium reaction, using structural formulae.

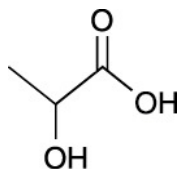
[2]

- (ii) The chemist uses concentrated sulfuric acid in carrying out the esterification.

Suggest **two** functions of the sulfuric acid in the esterification process.

[2]

5 The skeletal structure of lactic acid is shown below.



lactic acid

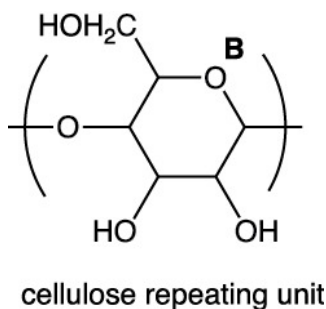
When left standing over concentrated sulfuric acid, lactic acid, $C_3H_6O_3$, forms a cyclic ester with molecular formula $C_6H_8O_4$.

Suggest how the cyclic ester is formed from lactic acid.

Give the structure of the cyclic ester.

[2]

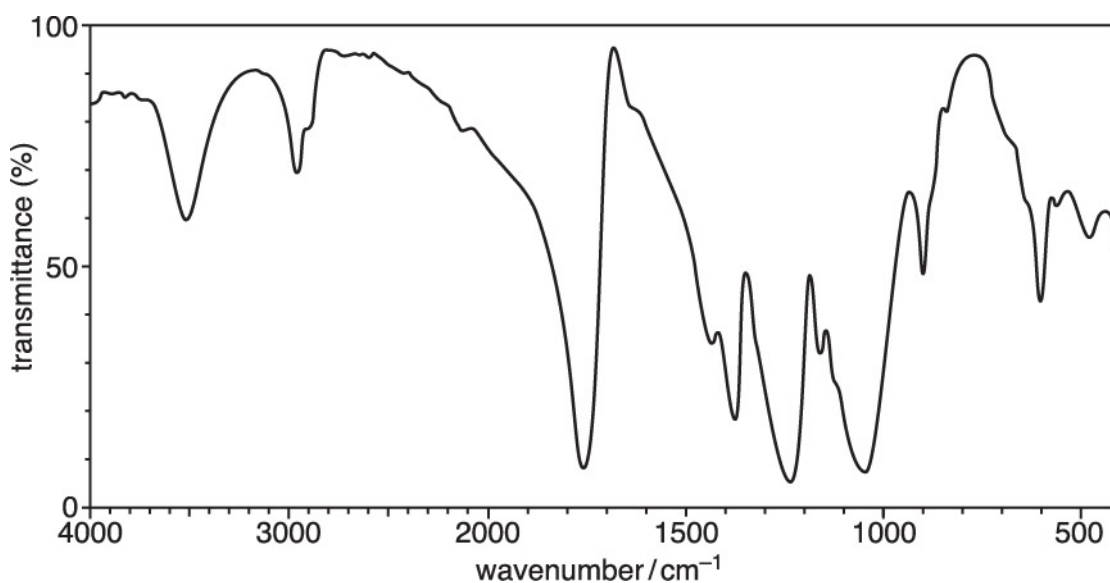
- 6 Film, used to make motion pictures, consists of a light-sensitive emulsion supported on a 'film base'. The film base is made from a polymer. Most of the polymers were based on cellulose. The repeating unit for cellulose is given below.



As well as cellulose triethanoate, cellulose diethanoate can be used for film. Infrared spectroscopy can be used to distinguish between these two films.

Give evidence from the infrared spectrum below to identify which of these two film bases was used.

Explain your answer.



[2]

7 Choose the statement that is **not** a principle of 'green chemistry'.

- A Cleaning up waste after it is formed.
- B Keeping the atom economy as high as possible.
- C Use of selective catalysts.
- D Choosing reactants to avoid explosions.

Your answer

☐

[1]

8 A white solid has the following properties:

It all melts at the same temperature.

It gives a purple colour with neutral $\text{FeCl}_3(\text{aq})$.

There is fizzing when $\text{Na}_2\text{CO}_3(\text{aq})$ is added.

The white solid could be

- A A mixture of a phenol and a carboxylic acid.
- B A compound with phenol and carboxylic acid functional groups.
- C A phenol.
- D A carboxylic acid.

Your answer

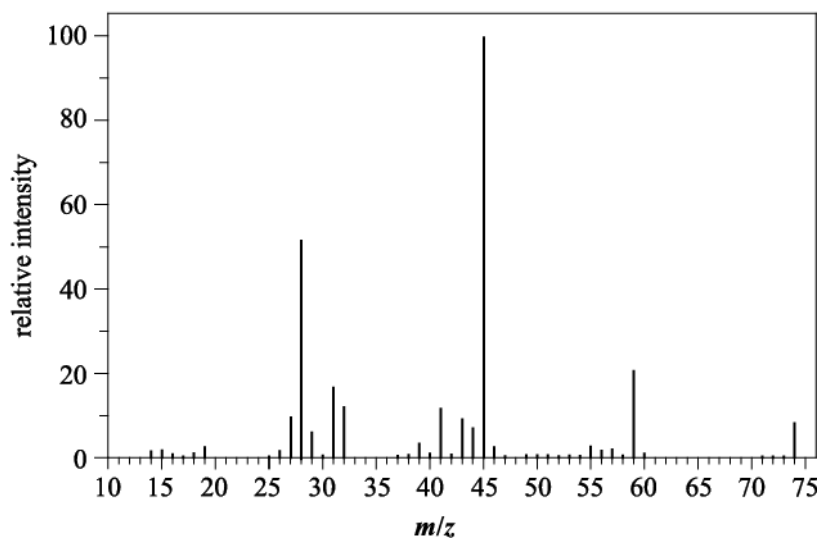
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[1]

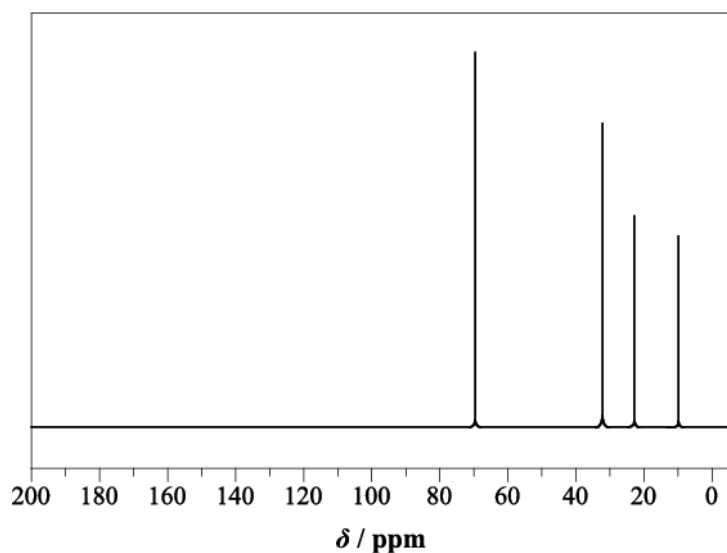
9 Ethanol is sometimes used as a biofuel to replace petrol in car engines. However it has several disadvantages.

* The mass spectrum and ^{13}C NMR spectrum for compound **A** are given below.

Mass spectrum (Compound A)



^{13}C NMR spectrum (Compound A)



Use the information below and the spectral data given on the previous page to work out the **structural formulae** of compounds **A**, **B**, **C** and **D**.

Compound **A** has the molecular formula $\text{C}_x\text{H}_y\text{O}$.

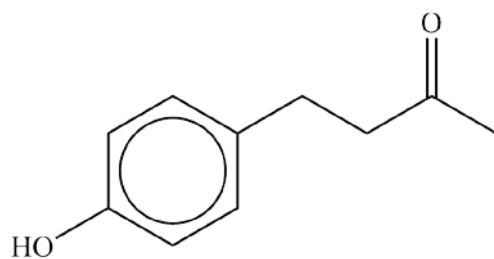
Compound **A** reacts when heated with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ to form compound **B**.

Compound **B** does **not** react with Tollens' reagent or NaOH .

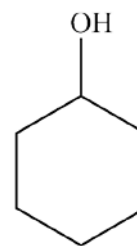
Compound **A** reacts with heated Al_2O_3 to form two unsaturated compounds, **C** and **D**.

[illegible]

10(a) * The structures of raspberry ketone and cyclohexanol are shown below.



raspberry ketone



cyclohexanol

The difference between the structures of the carbon ring in raspberry ketone and cyclohexanol has an effect on the chemical properties of the hydroxyl group.

Describe the difference between the structures of the two carbon rings and how the reactions of the hydroxyl group are different in the two compounds.

Include examples, and at least two equations.

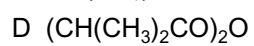
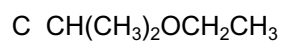
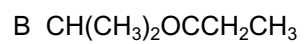
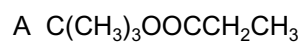
[6]

- (b) Raspberry ketone reacts with chloromethane in the presence of anhydrous aluminium chloride to form a mixture of two structural isomers.

What technique could be used to show that two organic products are present in the mixture?

-----[1]

11 Which formula represents an ester?

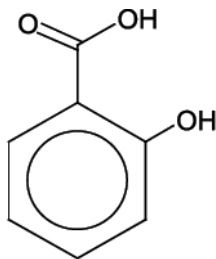


Your answer

[1]

12(a) Many compounds extracted from coal tar were used as raw materials for the chemical industry in the late 19th century.

One of these compounds was phenol which can be converted to 2-hydroxybenzoic acid.



2-hydroxybenzoic acid

Aspirin has the same pain-killing properties as 2-hydroxybenzoic acid but fewer side-effects.

2-hydroxybenzoic acid can be converted to aspirin by esterifying the phenol group with ethanoic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$.

Give the equation for this reaction, using structural formulae.

[2]

(b) Some students make a sample of aspirin which is contaminated with 2-hydroxybenzoic acid.

The students carry out thin layer chromatography on the contaminated sample of aspirin.

They dissolve the contaminated aspirin, put a spot on a TLC plate and place the plate in a suitable solvent. They wait until the solvent has risen to the top of the plate.

They then made the substances visible using iodine vapour.

Sketch and label the expected result.

	2-hydroxybenzoic acid	aspirin
R _f value	0.32	0.80

[1]

(c)

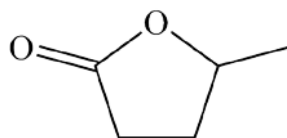
The students then purify the sample by recrystallization.

Suggest **one** factor that influences the choice of solvent for this.

Explain your answer.

[1]

- 13 The compound 'GMV' is a potential 'green fuel' as it can be made from glucose and can be blended with petrol.



GMV

GMV can be made in the laboratory by reacting a single organic compound with concentrated sulfuric acid.

Give the structure of this organic compound and state how it forms GMV.

----- [2]

- (i) Draw, in the space below, the **skeletal formula** of the structure you would expect to obtain when ambrinol (Fig. 2) reacts with bromine.

[1]

- (ii) How many peaks would you expect in the ^{13}C NMR spectrum of ambrinol?

[1]

- (iii) Give the number of chiral centres in ambrinol.

Explain how you arrived at your answer.

[2]

- (iv) Discuss whether or not you would expect the enantiomers of ambrinol to smell the same.

[2]

- (b) Describe chemical tests, resulting in colour changes, by which you could distinguish between vanillin, guaiacol and benzaldehyde (Fig. 3).

Include a positive reaction for each substance.

[4]

- (c) Explain the significance of the graph (shown in Fig. 3) to Turin's theory.

Give the cause of the peak just above 3000 cm^{-1} .

[3]

- (d) This part of the question explores Turin's use of isotopes to support his theory.

- (i) State the meaning of the term *isotopes*, using the terms *atomic number* and *mass number*.

Give the number of neutrons in an atom of deuterium and an atom of ^{13}C .

meaning: -----

number of neutrons: -----

[2]

- (ii) A sample of carbon dioxide contains 98.89% ^{12}C , the rest being ^{13}C .

Calculate the A_r value for the carbon in the carbon dioxide to **two** decimal places.

$A_r =$ _____ [1]

(iii) Draw the **skeletal formula** of 'acetophenone'.

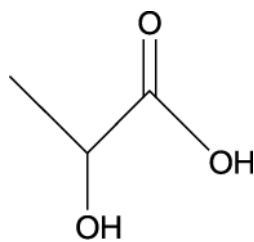
State the difference between this molecule and 'acetophenone-d₈' (**page 5**).

----- [2]

(iv) * Discuss examples from the article that support Turin's theory and **not** the 'lock and key' theory.

----- [6]

15 The skeletal structure of lactic acid is shown below.



lactic acid

When dried with concentrated sulfuric acid, lactic acid forms a cyclic ester with molecular formula $C_6H_8O_4$.

Suggest how the cyclic ester is formed from lactic acid.

Give the structure of the cyclic ester.

----- [2]

16(a) Ethanedioic acid can be made by oxidising 'ethylene glycol', $\text{HOCH}_2\text{CH}_2\text{OH}$.

- (i) Give the systematic name of ethylene glycol.

-----[1]

- (ii) Ethylene glycol has two primary alcohol groups.

Explain the meaning of the term *primary alcohol*.

-----[1]

- (b) Ethylene glycol can be oxidised under different conditions from the ones used in (e).

The compound 'glyoxal' is produced.

Glyoxal has two functional groups that are the same.

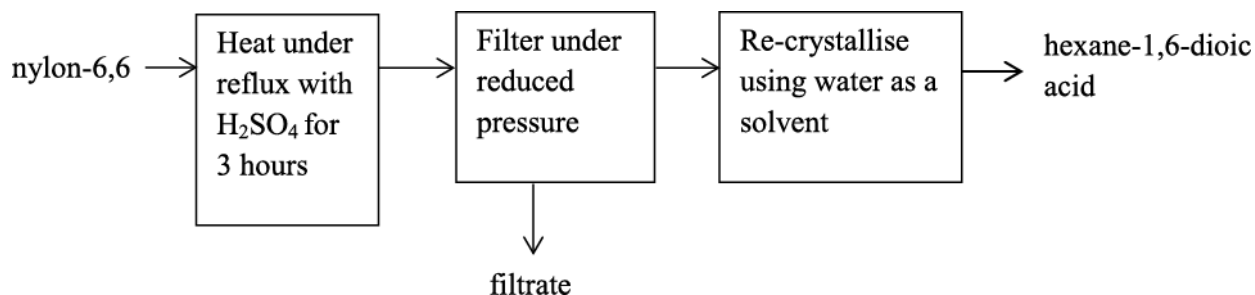
- (i) Name the functional group.

-----[1]

- (ii) Describe a chemical test for this group, not involving acid dichromate.
Give the positive result of the test.

-----[2]

17(a) Scientists are investigating how best to recycle polymers including nylon-6,6. One approach is to break the polymer down into its monomers which can be re-used. The following flow chart shows how hexane-1, 6-dioic acid can be produced from nylon-6, 6.



(i) What is meant by *heating under reflux*?

----- [2]

(ii) Draw a labelled diagram to show how crystals of hexane-1, 6-dioic acid can be collected by filtration under reduced pressure.

[3]

(iii) Describe the main steps involved in carrying out the recrystallization of hexane-1, 6-dioic acid using water as a solvent.

In your account, describe what property of hexane-1, 6-dioic acid this process depends upon.

[4]

(iv) 0.40 g of pure hexane-1, 6-dioic acid ($M_r = 146$) are obtained from 2.0 g of nylon-6, 6.

Calculate the percentage yield of the reaction.

yield = _____ % [2]

(b) The student adds excess sodium hydroxide solution to the filtrate. The student notices that the mixture develops a 'fishy' smell characteristic of an amine.

Suggest the shortened structural formula of the compound responsible for the 'fishy' smell.

[1]

18(a) A student carries out an experiment to compare the smells of different esters.

The student follows the procedure given below.

- Prepare some small test-tubes by adding one drop of concentrated sulfuric acid to each.
- Add 10 drops of a carboxylic acid to the sulfuric acid in one test-tube.
- Add 10 drops of an alcohol to the mixture.
- Carefully lower the tube into a beaker of hot water.
- After 1 minute remove the tube and, when cool, pour the mixture into a boiling tube half-full of sodium carbonate solution.
- Smell the product by gently wafting the odour towards your nose with your hand.
- Repeat this procedure with different combinations of carboxylic acid and alcohol.

(i) What is the purpose of adding concentrated sulfuric acid to each tube?

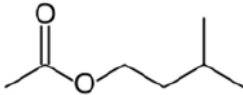
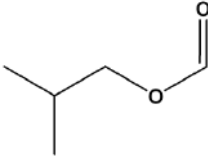
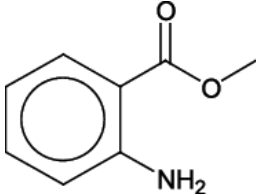
-----[1]

(ii) Why is the mixture poured into the boiling tube of sodium carbonate solution and describe the expected observation.

-----[1]

- (b) The student uses various combinations of alcohol and carboxylic acid. These are shown in the table below with the smell of the ester formed.

Complete the table below by filling in the blanks.

Alcohol	Carboxylic acid	Structure of Ester	Smell
pentan-1-ol	ethanoic acid		pears
3-methylbutan-1-ol			bananas
2-methylpropan-1-ol	Methanoic acid		raspberry
	anthranilic acid		grape

[3]

- (c) The student tries to distil off some pure raspberry ester as its boiling point is lower than either reactant.

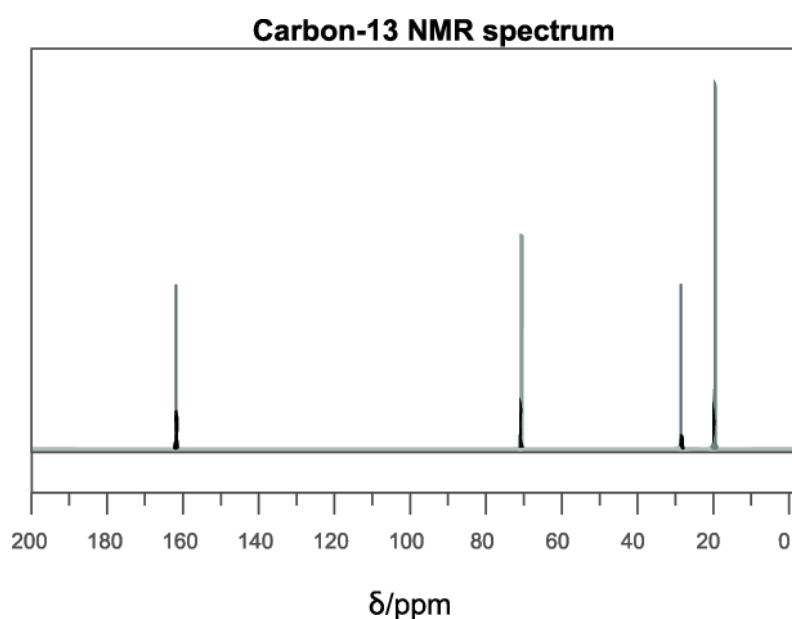
The student repeats the procedure with a larger quantities of reactants. After adding the sodium carbonate the student:

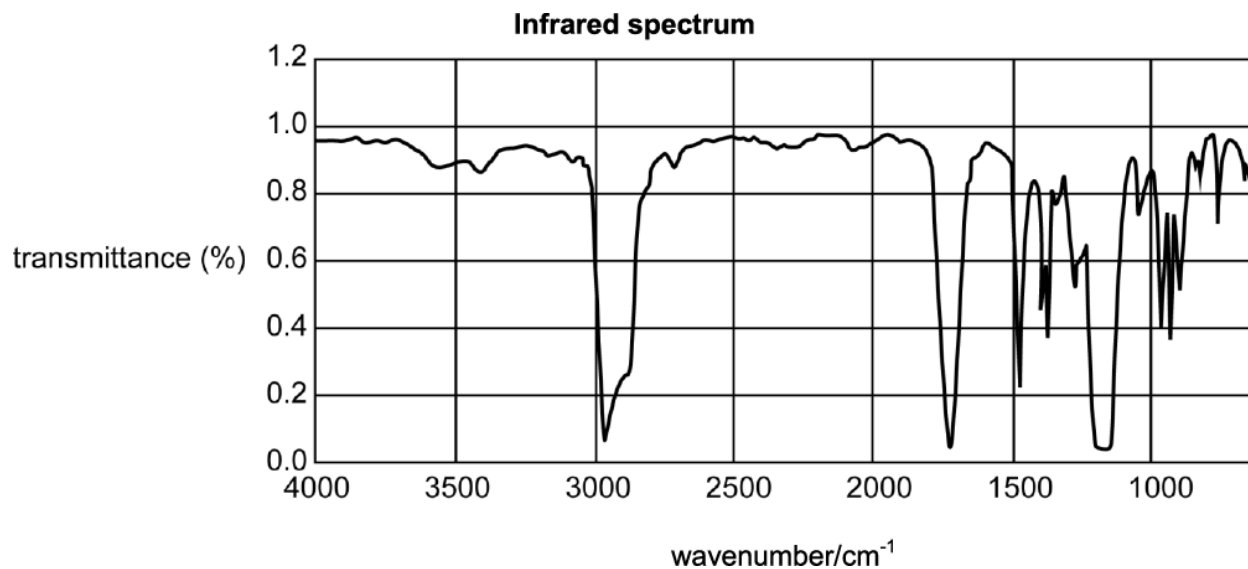
- puts the reaction mixture into a separating funnel and runs off the bottom aqueous layer
- swirls the top ester layer with anhydrous sodium sulfate for 20 minutes
- distils the mixture, collecting the ester.

- (i) State the role of the anhydrous sodium sulfate.

-----[1]

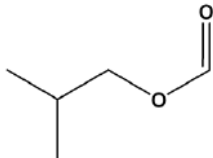
- (ii) * The student gets a local laboratory to run a carbon-13 NMR and an infrared spectrum on the product to confirm whether the preparation had produced the pure raspberry ester.





You may do rough working on this page but it will not be marked.

Some information from the table on page 3 is re-printed here.

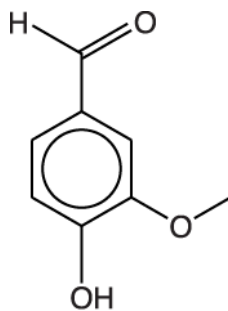
Alcohol	Carboxylic Acid	Structure of Ester	Smell
2-methylpropan-1-ol	Methanoic acid		raspberry

Use information from both spectra to explain why they show that the distillation produced the pure raspberry ester.

[6]

19(a) Vanillin is the main component of natural vanilla extract used to flavour foods.

Artificial vanilla flavouring is often just a solution of synthetic vanillin.



Vanillin

(i) Name the functional groups, other than the benzene ring, present in vanillin.

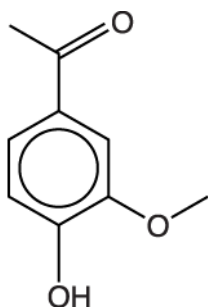
----- [2]

(ii) In plants, vanillin is sometimes oxidised to vanillic acid.

Give the **name(s)** of the reagent(s) that can be used for such an oxidation in the laboratory.

----- [1]

(b) Other compounds are sometimes added to artificial vanilla flavouring. One such compound is apocynin.



Apocynin

- (i) An unlabelled substance is thought to be either vanillin or apocynin.

An infrared spectrum is used to identify the substance.

The unlabelled substance has peaks at 3310 cm^{-1} (broad), 3010 cm^{-1} (medium-strong), 2930 cm^{-1} (medium-strong), and 1705 cm^{-1} (strong).

Identify the bonds responsible for these peaks and identify the substance.

[3]

- (ii) Suggest **one** way in which mass spectrometry could be used to distinguish between vanillin and apocynin. Assign m/z values to any peaks you describe.

[2]

- (iii) Apocynin is a solid that is insoluble in cold water but soluble in hot water.

Describe how a sample of solid apocynin containing water-soluble impurities can be purified in the laboratory.

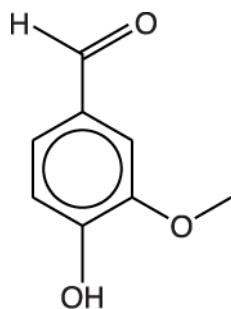


In your answer, you should use appropriate technical terms, spelled correctly.

[3]

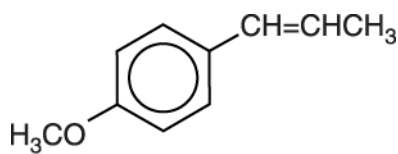
(c) Vanillin reacts with cyanide ions and dilute acid.

Complete the diagram below to show the mechanism of this reaction, including the structure of the final product. Use curly arrows, electron pairs, bond polarities and charges as appropriate.



[4]

20(a) The substance anethole is present in some alcoholic drinks such as 'ouzo'. Alcoholic drinks containing anethole go cloudy when water is added.



anethole

(i) Give the molecular formula of anethole.

-----[1]

(ii) Name the saturated functional group in anethole.

-----[1]

(iii) Naturally occurring anethole is an *E* isomer.

Draw the structure of the *E* isomer.

[1]

(b) The double bond in anethole reacts with bromine.

Draw the **skeletal** formula of the compound produced.

[1]

(c)

(i) Give the mechanism of the reaction of bromine with ethene, showing whole and partial charges, curly arrows, and the final product.

[3]

(ii) Ethene is brominated using **aqueous** bromine.

Suggest why $\text{CH}_2\text{OHCH}_2\text{Br}$ is formed but $\text{CH}_2\text{OHCH}_2\text{OH}$ is **not** formed.

[2]

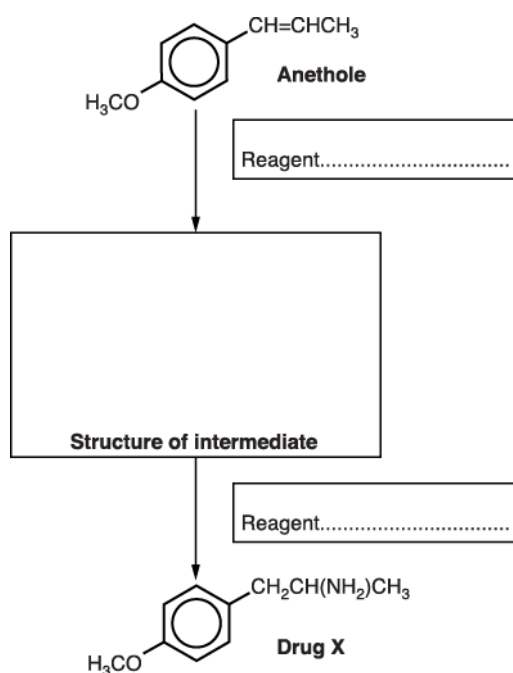
Explain this statement in terms of hydrogen bonding, indicating how these bonds are formed.

[5]

(e) Anethole can be made into drug X.

(i) Complete the flowchart for this synthesis.

Write your answers in the boxes.



[3]

(ii) Drug X is reacted with HCl(aq) .

Draw the structure of the organic product.

[1]

(iii) Drug X has a chiral centre but anethole does not.

Explain this statement.

[3]

(iv) Draw diagrams to show the enantiomers of drug X.



[2]

(v) Explain how infrared spectroscopy could be used to show that all the anethole has been converted into drug X.

[2]

21(a) The product of hydrolysis of t-butyl bromide is t-butyl alcohol.

What **type** of alcohol is $(\text{CH}_3)_3\text{COH}$? Explain why.

[1]

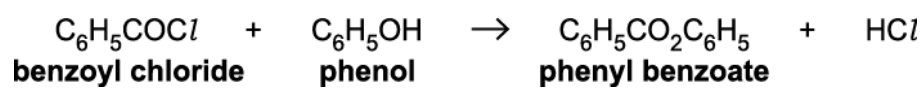
- (b) Compound **A** is an isomer of $(\text{CH}_3)_3\text{COH}$ that exists as two enantiomers.
Compound **A** can be oxidised to organic compound **B**.

Deduce the **skeletal** formulae and names of compounds **A** and **B**.

Compound	Skeletal formula	Name
A		-----
B		-----

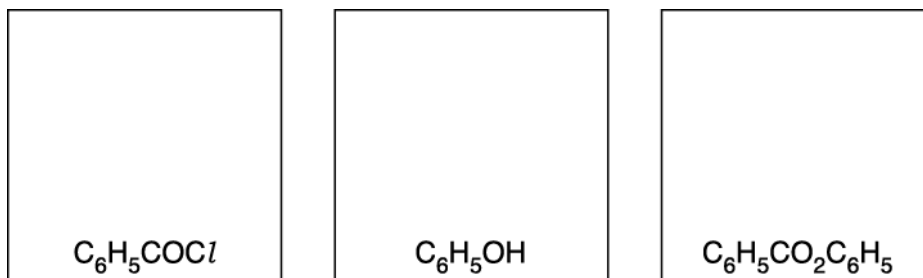
[4]

22(a) Two students aim to prepare a sample of phenyl benzoate using the reaction below.



Draw structural formulae for the organic compounds in the boxes below.

[1]



- (b) The students weigh out the phenol in a weighing bottle and shake it with excess alkaline benzoyl chloride. They collect and purify their product and weigh it in a sample bottle. The students' results are given below.

Mass of weighing bottle + phenol / g	27.70
Mass of weighing bottle after emptying / g	22.68
Mass of sample bottle / g	6.16
Mass of sample bottle + purified phenyl benzoate / g	11.50
Melting point of phenyl benzoate / °C	67–69

- (i) Calculate the percentage yield of the phenyl benzoate.

percentage yield = _____ % [3]

- (ii) Suggest why the percentage yield is relatively low.

----- [1]

- (iii) A textbook value for the melting point of phenyl benzoate is 69 °C.

Comment on the purity of the sample produced by the students.

----- [1]

25(a) Esters have many uses in organic chemistry, including in polymers.

Some students want to determine the equilibrium constant for the esterification reaction in **equation 33.1** in acidic conditions.



They set up their experiment with known masses of ethanol, ethanoic acid and concentrated sulfuric acid catalyst.

They place the reactants in a stoppered bottle and wait a week for equilibrium to be established.

Suggest how the students could find the amount of ethanoic acid in the bottle at equilibrium.

----- [2]

- (b) By using the method from (a), the students find that the amount of ethanoic acid present at equilibrium is 0.123 mol.

They produce the table below.

Substance	Mass present at the start / g	Amount present at the start / mol	Amount present at equilibrium / mol
ethanol	15.8		
ethanoic acid	21.0		0.123
ethyl ethanoate	0	0	
water	0	0	

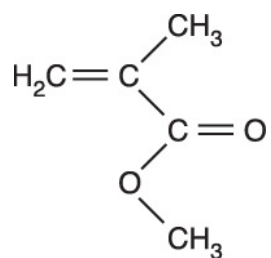
Carry out appropriate calculations to fill in the blanks in the table.

Use figures from the table to work out a value for the equilibrium constant, K_c , of the reaction in equation 33.1.

$K_c =$ _____ [4]

- (c) Another ester is the monomer for the polymer polymethyl methacrylate or PMMA. PMMA is often used to make lightweight transparent materials as a replacement for glass.

The monomer has the structure shown below.



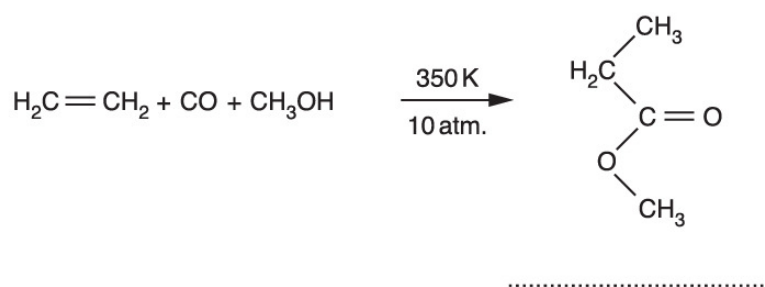
Draw the structural formula for **one** repeating unit of the polymer.

[1]

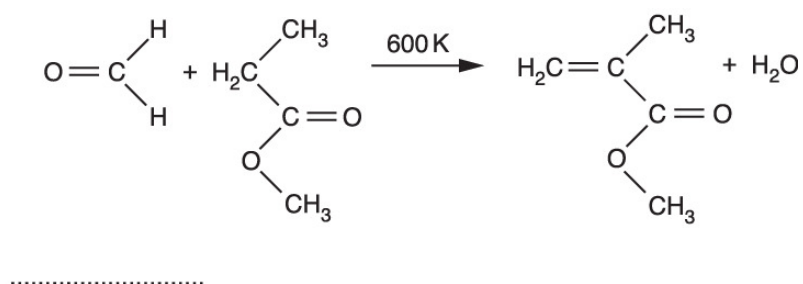
(d) The monomer can be made in the following reaction sequence.

Give the systematic names of two of the compounds on the dotted lines below their structures.

Stage 1:



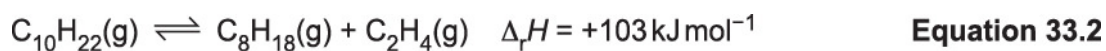
Stage 2:



[1]

- (e) The ethene used in **stage 1** comes from thermal cracking of long chain alkanes from crude oil in the presence of steam.

One such reaction is shown below.



Substance	Entropy / $\text{J mol}^{-1} \text{K}^{-1}$
$\text{C}_{10}\text{H}_{22}$	+425.9
C_8H_{18}	+361.1
C_2H_4	+219.5

Use the entropy values given to find the minimum temperature needed for the forward reaction to be feasible.
Give your answer to an **appropriate** number of significant figures.

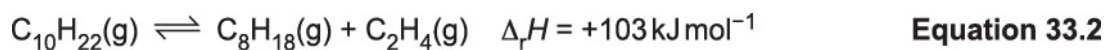
minimum temperature = _____ K [3]

- (f) Give the effects that the following changes have on the value of K_c for the reaction in **equation 33.2**.

Change	Increased temperature	Increased pressure	Use of a catalyst
Effect on K_c			

[2]

(g) The yield of the reaction in **equation 33.2** is typically 50%.



Calculate the volume (in dm^3) of ethene produced when 25.0 kg of decane are cracked at 900 K and a pressure of 150 kPa.

volume of ethene = _____ dm^3 [3]

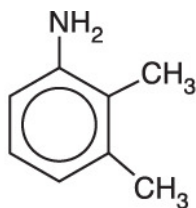
(h) An alternative method of obtaining ethene is catalytic cracking using zeolite catalysts.

Explain the advantage to the environment of this method over steam cracking.

----- [1]

26(a) Coal tar provides the raw materials for many painkilling drugs and dyestuffs. One such drug, 'mefenamic acid', is also being investigated as a possible treatment for Alzheimer's disease. Mefenamic acid is made from 2,3-dimethylphenylamine.

Distillation is used to separate the compound 2,3-dimethylphenylamine from coal tar.



2,3-dimethylphenylamine

- (i) Draw a labelled diagram to show how distillation can be carried out in a laboratory to remove the more volatile component from a mixture.

Explain how the products are separated.

----- [3]

- (ii) The 2,3-dimethylphenylamine is contaminated with phenols. The mixture is shaken with hydrochloric acid in a separating funnel.

Give the equation for the reaction of 2,3-dimethylphenylamine with hydrochloric acid.

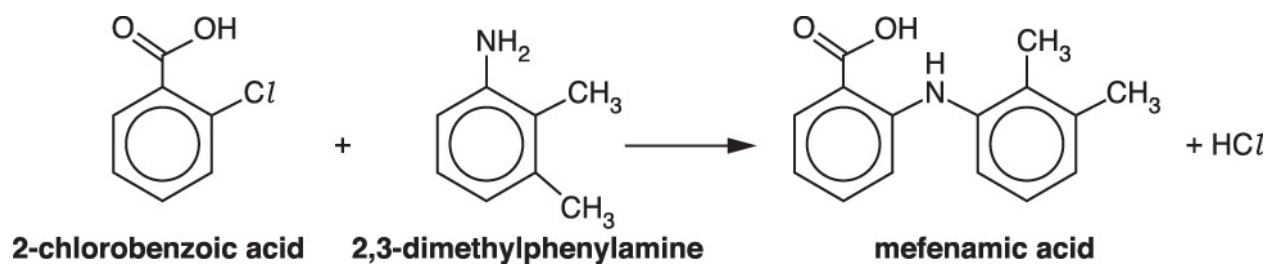
[1]

(iii) The aqueous layer is then run off.

Suggest how the 2,3-dimethylphenylamine can be obtained from the solution.

----- [2]

(b) The reaction to form mefenamic acid is shown below.



The yield of the reaction is 52%.

Calculate the mass of 2-chlorobenzoic acid (in kg) needed to produce 15.0 kg of mefenamic acid.

mass = _____ kg [3]

28 What is correct about a mass spectrum of a compound?

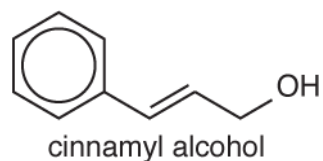
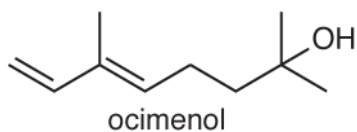
- A It shows the atoms produced from the compound.
- B It enables the M_r of the compound to be determined.
- C It has a small $M+1$ peak because of some ^2H atoms present in the compound.
- D The units of the x-axis are 'mass'.

Your answer

[1]

29(a) A perfume laboratory is investigating the molecules responsible for the smell of some common flowers.

Their investigations suggest that the following two liquid compounds are important in the characteristic smell of hyacinth flowers.



Acidified dichromate solution can be used to distinguish between these two compounds.

Only cinnamyl alcohol can be oxidised using acid dichromate.

Explain why this is so, and describe any colour changes you would expect to see.

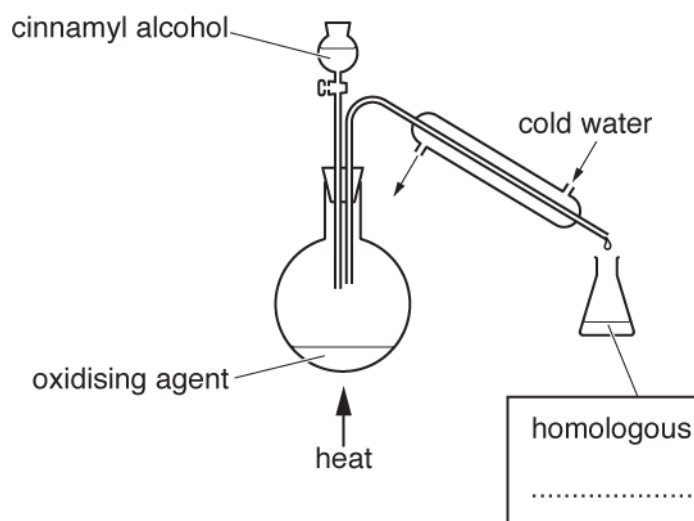
[2]

- (b) The products of the oxidation of cinnamyl alcohol by acid dichromate differ depending on the conditions. Two experiments are shown below.

Name, in the appropriate boxes below:

- the technique used in each set up
- the homologous series of the final product of oxidation

cinnamyl alcohol



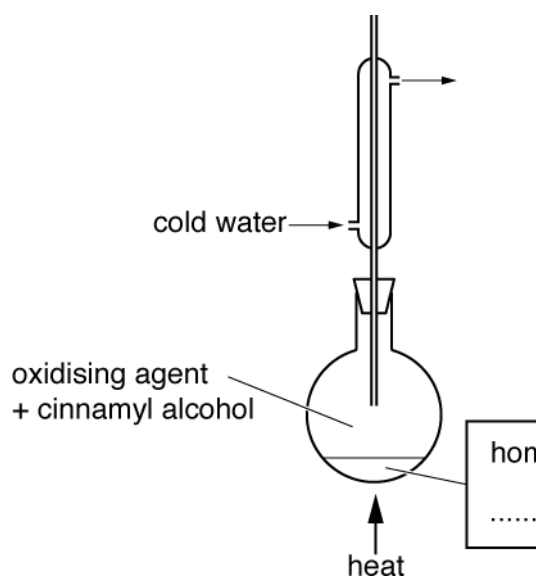
oxidising agent

heat

cold water

technique used

homologous series of product



cold water

oxidising agent + cinnamyl alcohol

heat

technique used

homologous series of product

[4]

- (c) Mass spectrometry can also be used to distinguish between ocimenol and cinnamyl alcohol. The molecular ion peak in a mass spectrum of ocimenol is at an m/z value of 154.

What m/z value would represent the molecular ion peak in a mass spectrum of cinnamyl alcohol?

m/z for cinnamyl alcohol molecular ion = ----- [1]

30(a) Sodium ethanoate is used as an 'acidity regulator' in foods.

Sodium ethanoate, CH_3COONa , can be made by reacting solutions of ethanoic acid, CH_3COOH , and sodium carbonate, Na_2CO_3 , in the laboratory.

(i) Write an equation for this reaction.

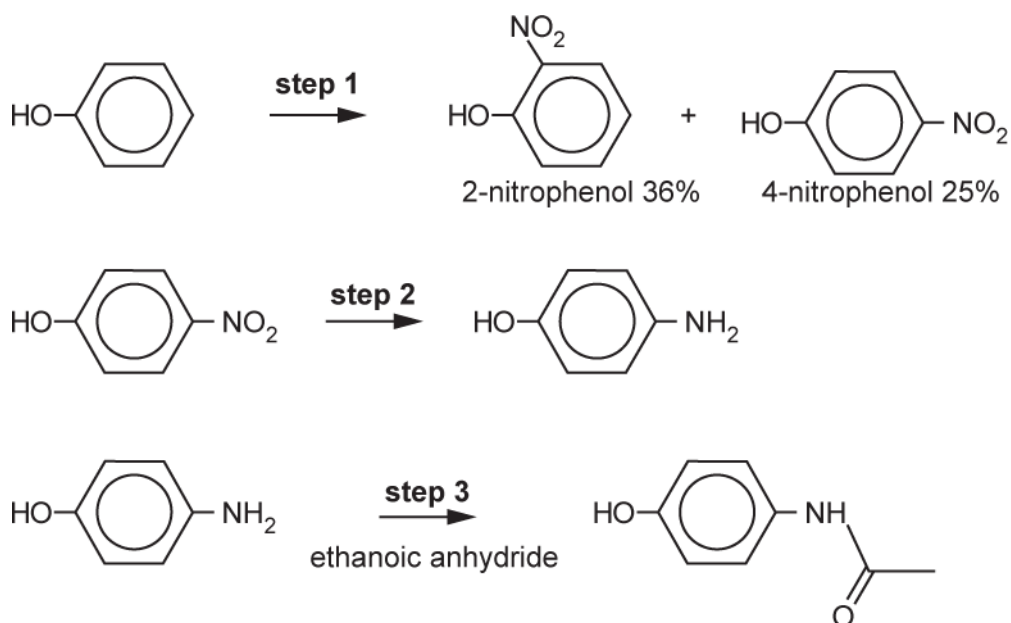
[2]

(ii) Calculate the volume (in cm^3) of $0.500 \text{ mol dm}^{-3}$ Na_2CO_3 that would react with 25.0 cm^3 of $0.450 \text{ mol dm}^{-3}$ CH_3COOH .

volume of $\text{Na}_2\text{CO}_3 = \text{-----} \text{ cm}^3$ [2]

(b) The ethanoate ion forms an alkaline solution in water.
Write an equation to show this.

[1]



- (i) The students want to make 5.0 g of 4-nitrophenol in **step 1**.
Calculate the mass of phenol they should start with.

Give your answer to an **appropriate** number of significant figures.

mass of phenol = ----- g [2]

- (ii) The two nitrophenols formed can be separated since they have different boiling points. 2-nitrophenol has a lower boiling point than 4-nitrophenol. This is because internal hydrogen bonding can occur in 2-nitrophenol.

Draw the structure of 2-nitrophenol with the -OH and -NO_2 groups shown as **full structural formulae**; show where the internal hydrogen bond would form.

[2]

(iii) Name the **type** of reaction that occurs in **step 2** and name the functional group that has been formed.

Type of reaction

Functional group formed

[1]

(iv) Write an equation for the reaction in **step 3**.

Use **skeletal** formulae for the organic compounds.

[2]

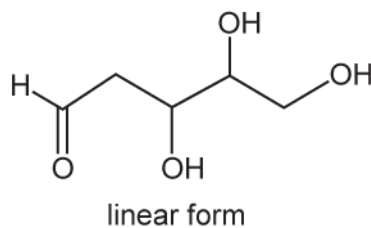
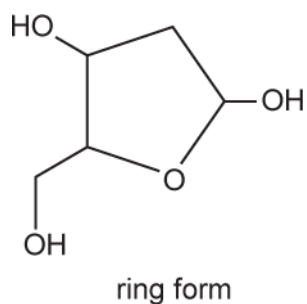
(v) The students purify the product from **step 3** by recrystallisation from water.

Describe the steps in the recrystallisation of a solid product from water. Indicate how insoluble and soluble impurities are removed.

----- [4]

32(a) Deoxyribose, $C_5H_{10}O_4$, has a vital role in our biochemistry as a component of DNA.

Deoxyribose exists in solution as several forms, two of which are shown below.



(i) Circle **all** the chiral centres on **both** structures above.

[1]

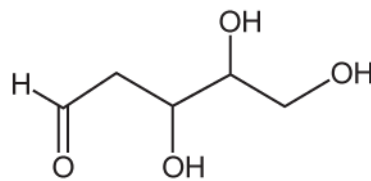
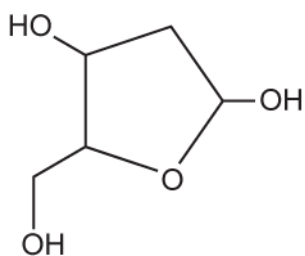
(ii) Name the functional group that is present in the linear form only.

-----[1]

(iii) Describe a laboratory test for the functional group identified in (a)(ii).

-----[2]

(iv) Circle a primary alcohol group on each structure below, giving a reason for your choice.



Reason

[2]

- (v) Explain why the reaction in which the linear form changes to the ring form is **not** condensation.

[1]

- (vi) Complete the equation that shows the reaction when the linear form changes to the ring form.
 $\text{--CHO} + \text{HO--} \rightarrow$

[1]

- (b) In DNA, deoxyribose is always present as the ring form.

The primary alcohol group in the ring form of deoxyribose and the alcohol group on the adjacent carbon condense with phosphate groups.

A sugar-phosphate backbone is formed.

Draw a section of the sugar-phosphate backbone.

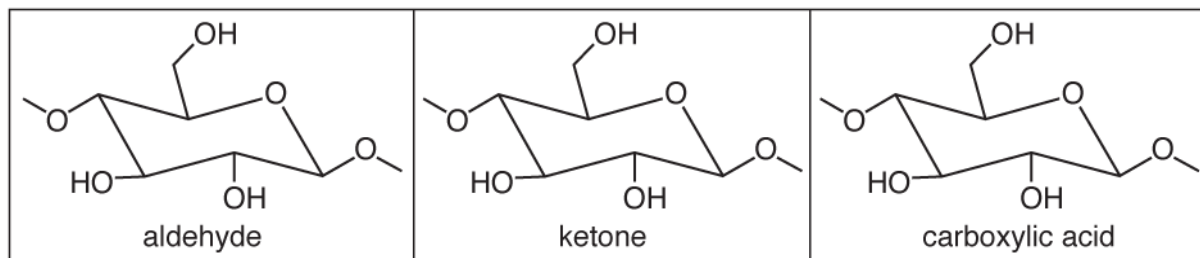
Show one deoxyribose and two phosphate groups.

[2]

33

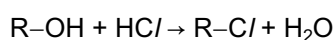
Hydroxyl groups in cellulose can be oxidised to aldehydes, ketones and carboxylic acids. The structures below each show part of a cellulose chain.

On each chain, **circle** the hydroxyl group(s) that can be oxidised to give the named group.



[3]

34 The reaction below produces a chloroalkane.



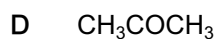
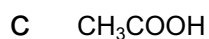
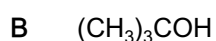
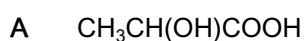
Which row shows the steps to purify the liquid product in the correct order?

A	Use a separating funnel	Distil	Dry	Remove unreacted HCl/
B	Remove unreacted HCl	Use a separating funnel	Dry	Distil
C	Remove unreacted HCl/	Use a separating funnel	Distil	Dry
D	Use a separating funnel	Remove unreacted HCl	Distil	Dry

Your answer

[1]

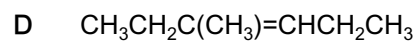
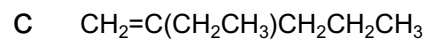
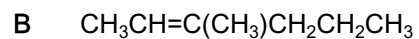
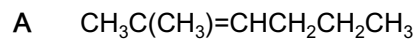
35 Which compound will react with acidified potassium dichromate(VI)?



Your answer

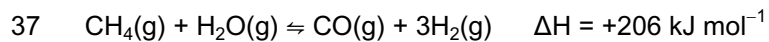
[1]

36 Which molecule will **not** be made when water is eliminated from $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3$?



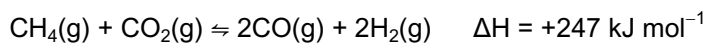
Your answer

[1]



Equation 36.1

A source of hydrogen is from the reaction shown in **equation 36.2**.



Equation 36.2

This is claimed to be a much greener process than that in **equation 36.1**.

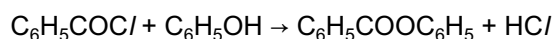
Comment on the validity of this statement, considering:

- the raw materials used
- the operating conditions
- the mole ratios.

[3]

38(a) This question refers to the Practical material that is supplied as Insert for H433/03, June 2018.

The equation for the reaction producing phenyl benzoate is as follows:



- (i) Draw a structural formula for phenyl benzoate, showing the bonding in the ester group.

[1]

- (ii) Use the student results to calculate the percentage yield of phenyl benzoate obtained from the practical.

percentage yield = ----- % [3]

(b)

- (i) In **step 8** of the procedure the water reacts with any remaining benzoyl chloride.

Write the equation for this reaction.

[1]

- (ii) Suggest and explain the reason for **step 13** in the procedure.

----- [1]

- (iii) Describe the practical procedure used to measure the melting point of an organic solid.
You **do not** need to discuss the type of melting point apparatus you use.

----- [3]

- (iv) What information can the students get from their melting point?

----- [1]

- (v) The recrystallisation procedure uses ethanol as the solvent.

Give the key properties needed by a solvent to be effective in recrystallisation.

----- [1]

- (c) The students carry out thin layer chromatography of the phenyl benzoate formed.
One student states that this will enable them to assess the purity of their product.

Comment on the validity of this statement.

You should describe any possible observations to back up your comments.

[4]

Propene gas, C_3H_6 , is obtained industrially from a variety of sources.

Propene is mainly used as a starting material for making polymers.

The mass spectrum of propene has several peaks including those at m/z 27 and 43.

(i) Give the species responsible for these peaks

27

43

[2]

(ii) Propene has an isomer, cyclopropane.

Explain why high-resolution mass spectrometry would **not** distinguish between propene and cyclopropane.

.....

.....

.....

.....

.....

.....

[2]

(iii) Suggest, with reasons, **two** spectroscopic methods (apart from mass spectroscopy) that would distinguish between cyclopropane and propene.

Method 1

Reason:

.....

.....

Method 2 -----

Reason: -----

[4]

40(a) Long chain alkanes can be cracked to provide better fuels and raw materials for the chemical industry. One such cracking reaction is shown in **equation 31.1**.

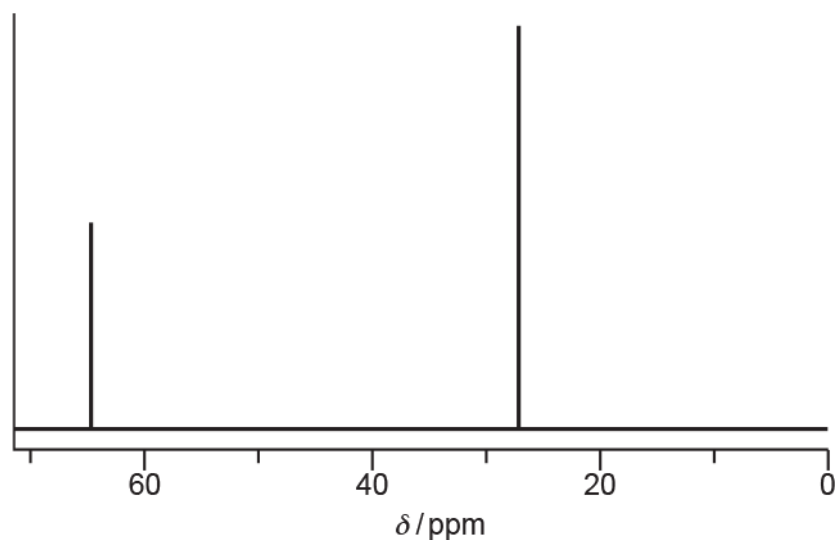


The propene produced in **equation 31.1** has many uses in the chemical industry.



One of the substances produced from propene is an alcohol used as a cleaner and de-icer.

The ^{13}C NMR spectrum of this alcohol is shown below.



Draw the **full** structural formula of the alcohol in the box below, giving your reasoning.

Reasoning
.....
.....
..... [2]

- (b) The alcohol from the part immediately above can be oxidised to a carbonyl compound.

Give the reagents and conditions to carry out this oxidation.

Reagents

Conditions

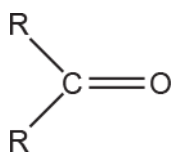
[1]

- (c) The carbonyl compound from the part immediately above can be reacted further to produce other raw materials.
For example, it reacts with HCN.

The formula of a carbonyl compound is shown below.

Give the mechanism for the reaction of this compound with cyanide ions followed by H^+ .
Show curly arrows, relevant dipoles and charges and give the formula of the product.

Name the type of reaction.

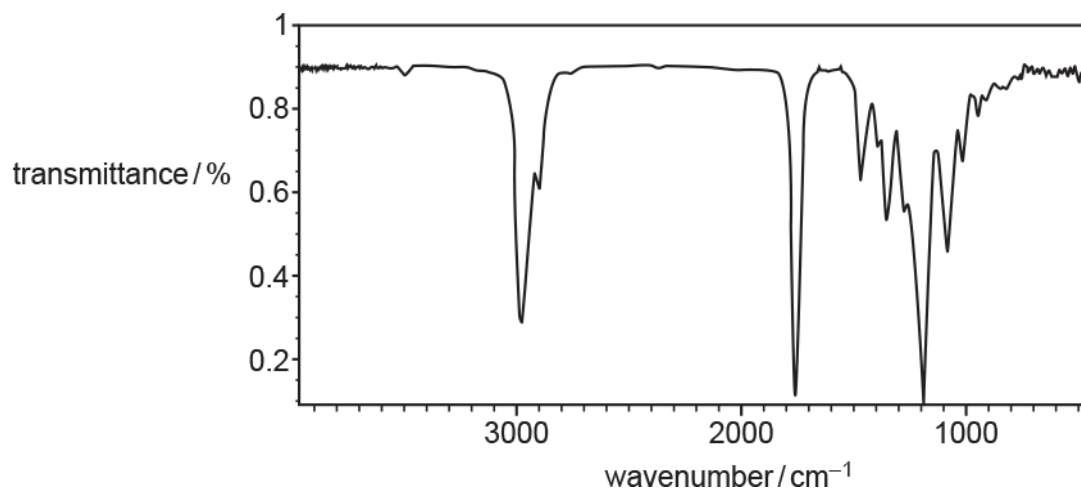


type of reaction [4]

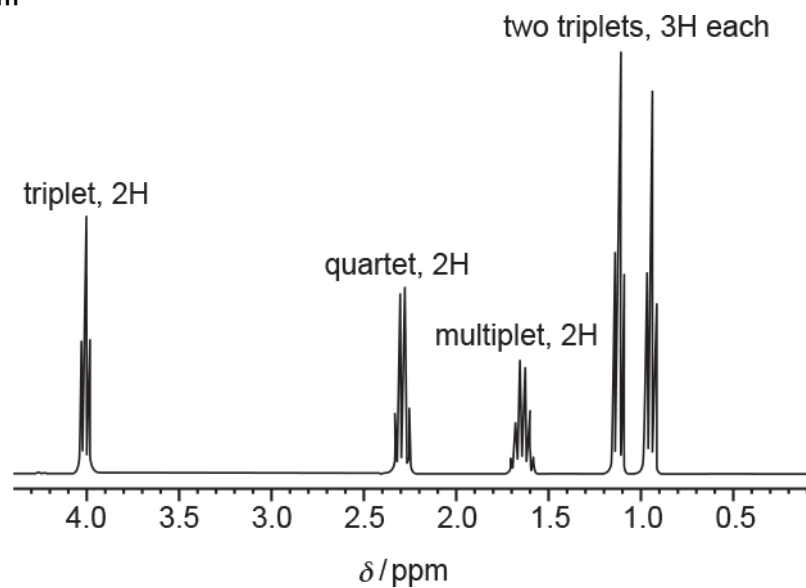
(d) *Compound A has six carbon atoms and can be made from propene using several steps.

The infrared, proton NMR and mass spectra for compound A are shown.

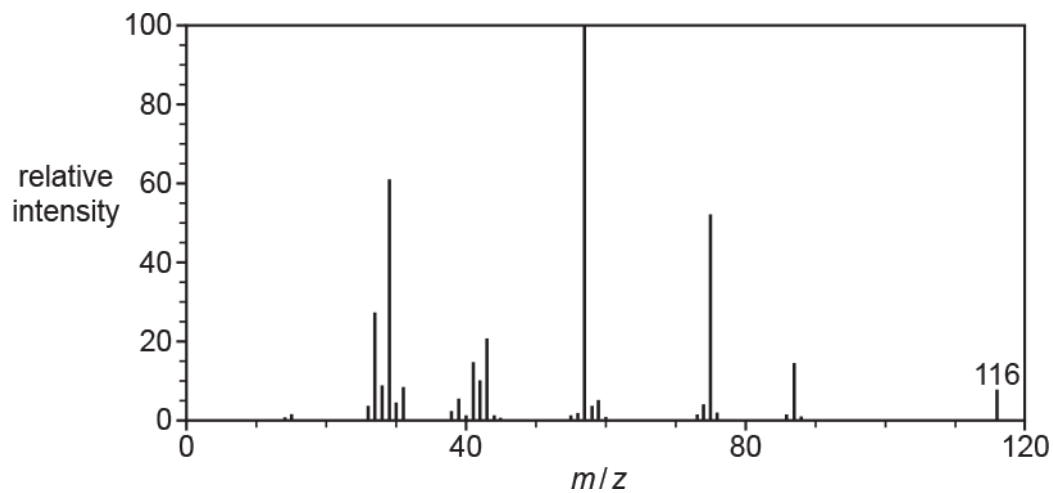
Infrared spectrum



Proton NMR spectrum



Mass spectrum



Use the information above to work out the structure of **compound A**.

Explain your reasoning, using evidence from each spectrum.

Structure of compound A

- 41 What is a principle of green chemistry? [6]
- A Heating a reaction to speed it up
 - B Improving the atom economy of a process
 - C Disposing of waste efficiently
 - D Using organic solvents

Your answer

[1]

42(a) Some students have two isomeric compounds **A** and **B** with the molecular formula $C_9H_{10}O$. They are both used in the perfume industry.

The students do some tests to find out which functional groups are present.

Compound **A** contains a phenol group.

How do the students identify the phenol group?

Test -----

Expected result ----- [1]

- (b) The students suspect that compound **B** contains an alcohol group and they want to find out what type of alcohol it is. They decide to see if compound **B** can be oxidised and if so whether the product is an aldehyde or a ketone.

They find that compound **B** is a primary alcohol.

- (i) Fill in the table to show the reagents, conditions and colour changes for their tests.

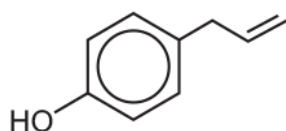
	Reagent(s)	Conditions	Colour change
Oxidation of alcohol			
Identification of aldehyde or ketone			

[3]

- (ii) Draw a **skeletal** formula for the **unsaturated** aromatic compound **B**.

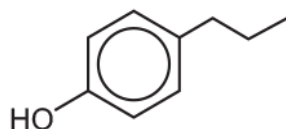
[1]

(c) The students are told that the structure of compound **A** is as shown below.



Other organic products can be made from compound **A**.

(i) Give the reagent and conditions to convert compound **A** into the compound shown below.



Reagent -----

Conditions ----- [1]

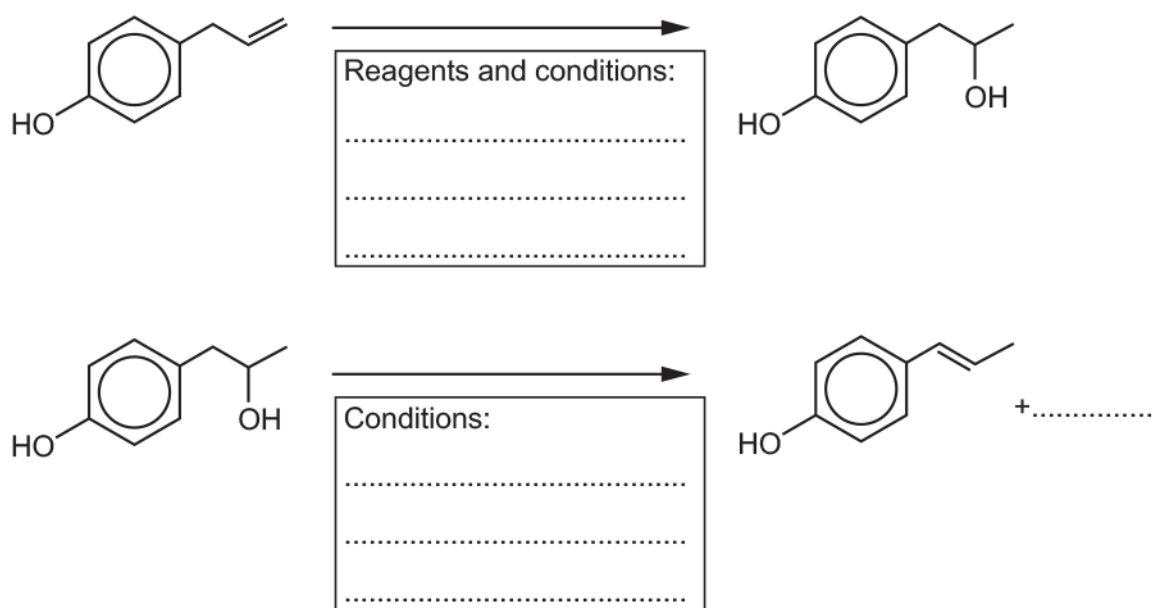
(ii) The students want to make the ethanoate ester of compound **A**.

Give the equation for a reaction to do this.

Use structural formulae for the organic molecules.

[2]

- (d) One of the students suggests the method below to change the position of the double bond on the side chain in two steps.



- (i) Complete the reaction sequence by writing on the dotted lines.

[2]

- (ii) Comment on the student's method of changing the position of the double bond.

.....

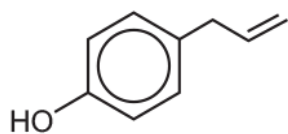
.....

.....

.....

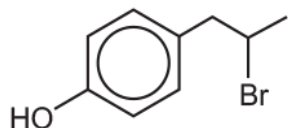
[2]

(e) Compound A is repeated below.



compound A

Hydrogen bromide reacts with compound A to give the compound shown below.



(i) Show the mechanism of the reaction of compound A with hydrogen bromide.

Use curly arrows and partial and full charges where appropriate.

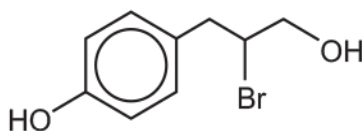
[2]

(ii) Compound A is reacted with aqueous hydrogen bromide containing dissolved sodium chloride.

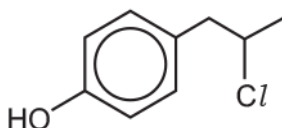
A student suggests that the products shown below are formed in addition to the product in part (i).

Comment on whether the student's suggestions are correct, giving the chemistry involved.

Product 1



Product 2



[3]

43(a) The students carry out the preparation using water as solvent.

Paracetamol is insoluble in water.

The students use the apparatus in Fig. 2.4 to separate the paracetamol from the reaction mixture.

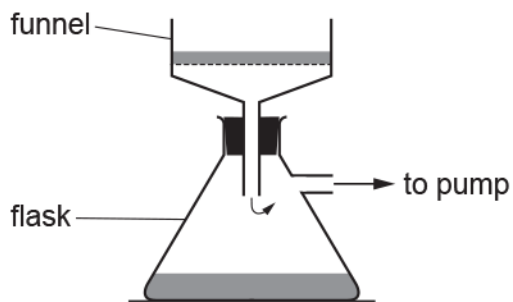


Fig. 2.4

- (i) Name the technique in Fig. 2.4 and explain how this apparatus is used to get a sample of impure solid paracetamol.

[3]

- (ii) Suggest a reason for using the technique in Fig. 2.4 rather than simple filtration.

[1]

- (b) A pair of chemistry students are asked to prepare a sample of paracetamol. They use the reaction shown in Fig. 2.1.

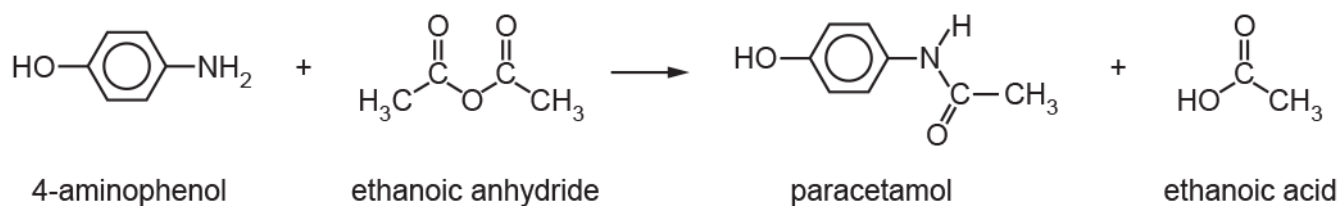
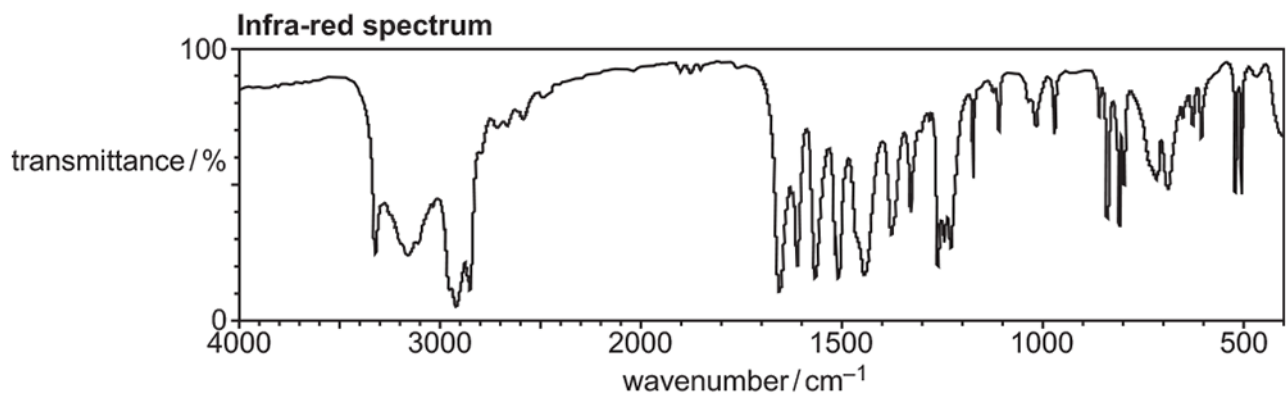


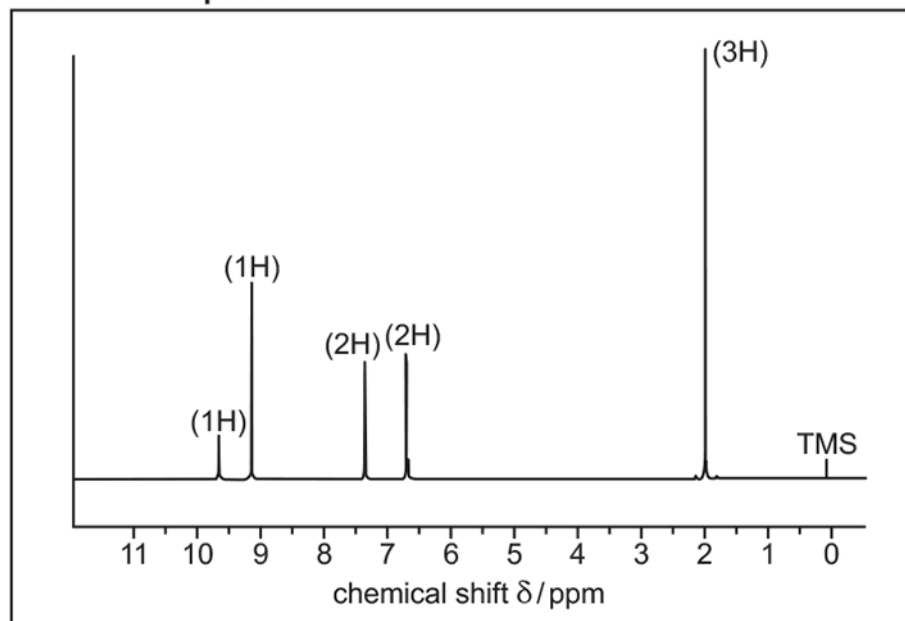
Fig. 2.1

The students sent pure samples of their reagents and products to a university lab. Spectra of all the compounds were produced.

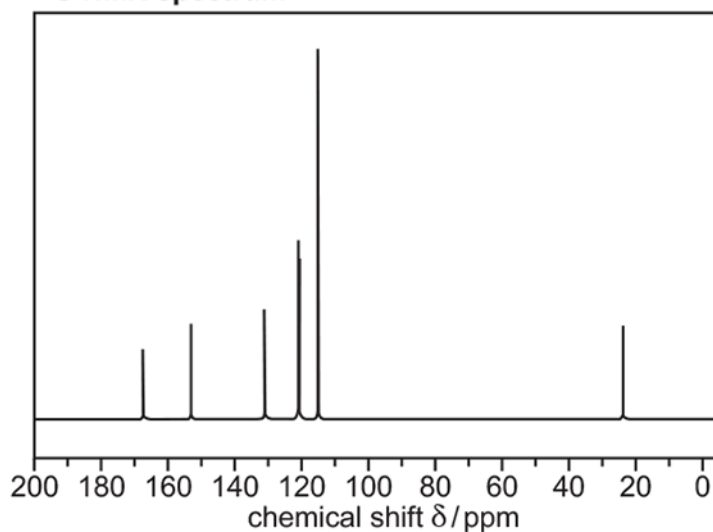
The spectra from **one** of the compounds are shown below.



Proton NMR spectrum



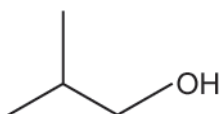
^{13}C NMR spectrum



Use pieces of evidence from **all** the spectra to identify the compound.

Blank lined paper for writing.

- 44 What happens when the compound shown is distilled with acidified potassium dichromate(VI)?



- A No new product is formed.
B An aldehyde is formed.
C A ketone is formed.
D A carboxylic acid is formed.

Your answer

☐

[1]

- 45 Which esterification reaction is correct?

- A $(\text{CH}_3\text{CO})_2\text{O} + \text{C}_2\text{H}_5\text{OH} \rightarrow \text{CH}_3\text{COOC}_2\text{H}_5 + \text{CH}_3\text{COOH}$
B $(\text{CH}_3\text{CO})_2\text{O} + 2\text{CH}_3\text{OH} \rightarrow 2\text{CH}_3\text{COOCH}_3$
C $\text{CH}_3\text{COOH} + \text{C}_6\text{H}_5\text{OH} \rightarrow \text{CH}_3\text{COOC}_6\text{H}_5 + \text{H}_2\text{O}$
D $\text{CH}_3\text{COC} + \text{C}_2\text{H}_5\text{OH} \rightarrow \text{C}_2\text{H}_5\text{COOCH}_3 + \text{HC}$

Your answer

☐

[1]

46 A manufacturer is producing a medicine.

The manufacturer considers the following ways of improving the process.

- 1 Raising the temperature to get the product more quickly.
- 2 Using a catalyst to get the product more quickly.
- 3 Reducing the number of steps in the process.

Which of these will result in a 'greener' process?

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

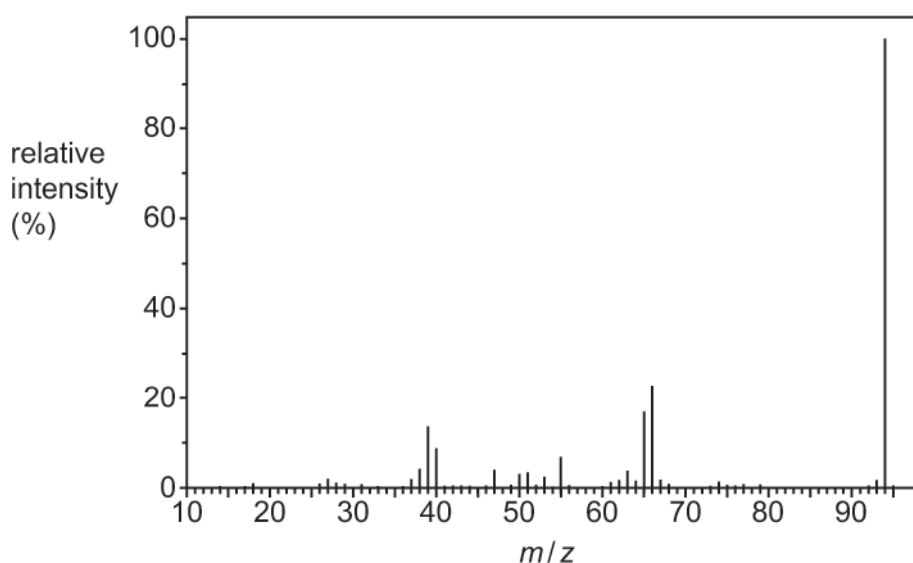
Propene can be reacted with benzene in the presence of oxygen to produce two useful products, **A** and **B**.

A student did some tests on the products and recorded their observations below. The student also obtained data about each product.

Student's tests on **Product A**:

Test	Observations
Add a drop of universal indicator.	orange colour produced
Add sodium carbonate solution.	no effervescence
Add neutral iron(III) chloride solution.	purple colour seen

The mass spectrum of **Product A**:



Student's tests on **Product B**:

Test	Observations
Add a drop of universal indicator.	stays green
Test with Tollens' reagent.	no change seen
React with NaBH ₄ .	B is reduced to an alcohol

Composition of **Product B**:

Element	C	H	O
Percentage by mass	62.1	10.3	27.6

You may do working on this page but it will not be marked.

Identify products A and B giving evidence from the student's observations and the data provided.

48(a) 'Fumaric acid' is used as an acidity regulator in food. 'Maleic acid' is a stereoisomer of fumaric acid. The structure of the two acids are shown in Fig. 4.1.

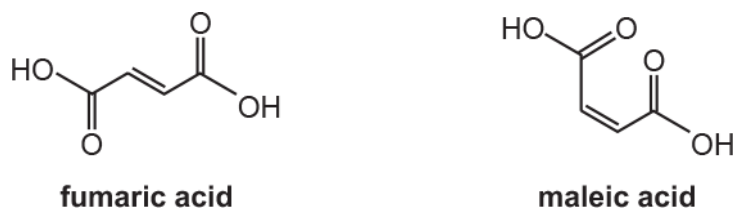


Fig. 4.1

Fumaric acid is made from maleic acid by an acid-catalysed isomerisation reaction.

A student suggests the mechanism shown in Fig. 4.2 for the reaction.

(i) Draw 'curly arrows' on Fig. 4.2 to complete the mechanism.

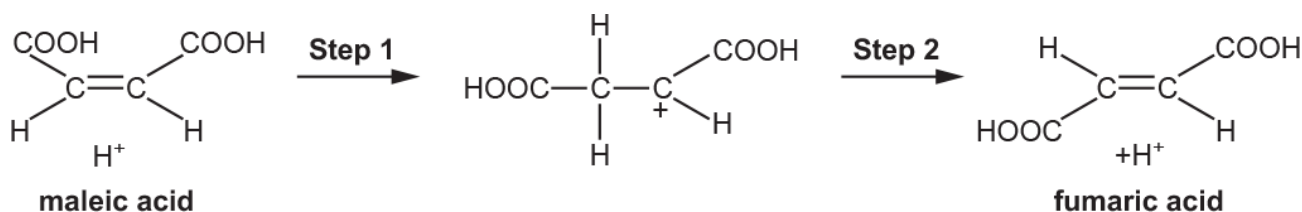


Fig. 4.2

[2]

(ii) Name the **type** of reaction that is occurring in **step 2**.

[1]

(iii) The student then reads that if $^2\text{H}^+$ ions are used for the isomerisation, then there isn't any ^2H found in the fumaric acid formed.

Does this support the student's mechanism in Fig. 4.2?

Explain your answer.

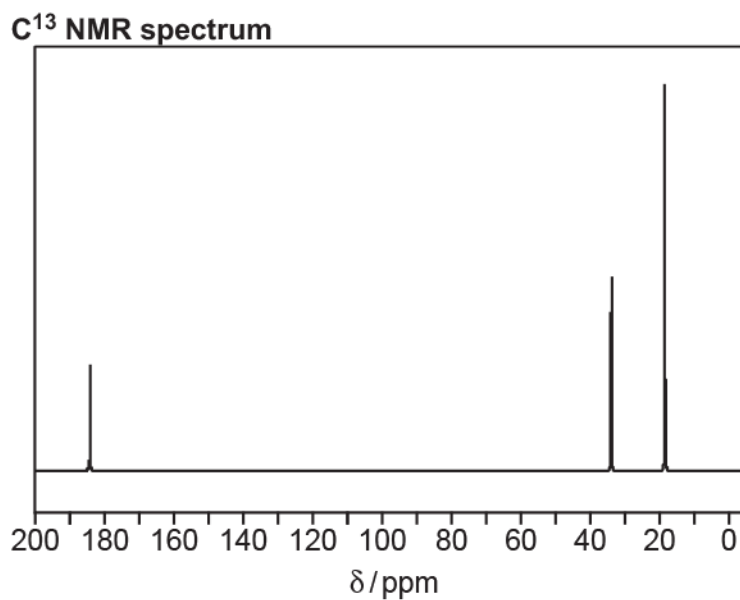
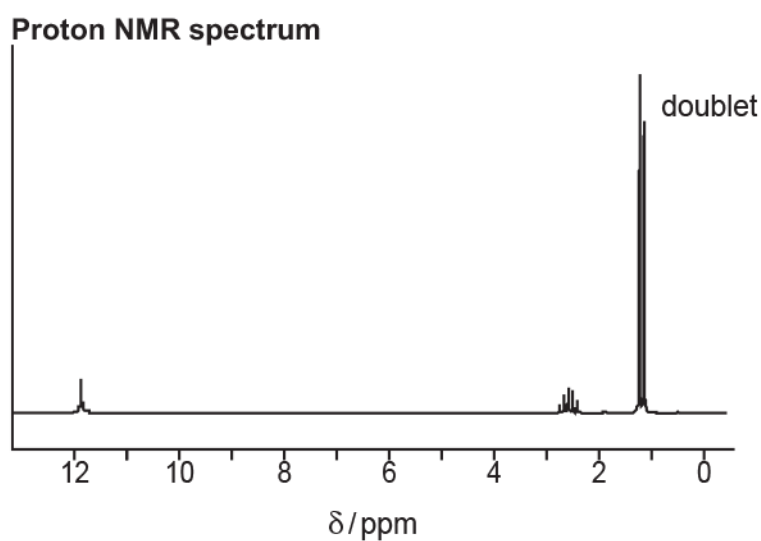
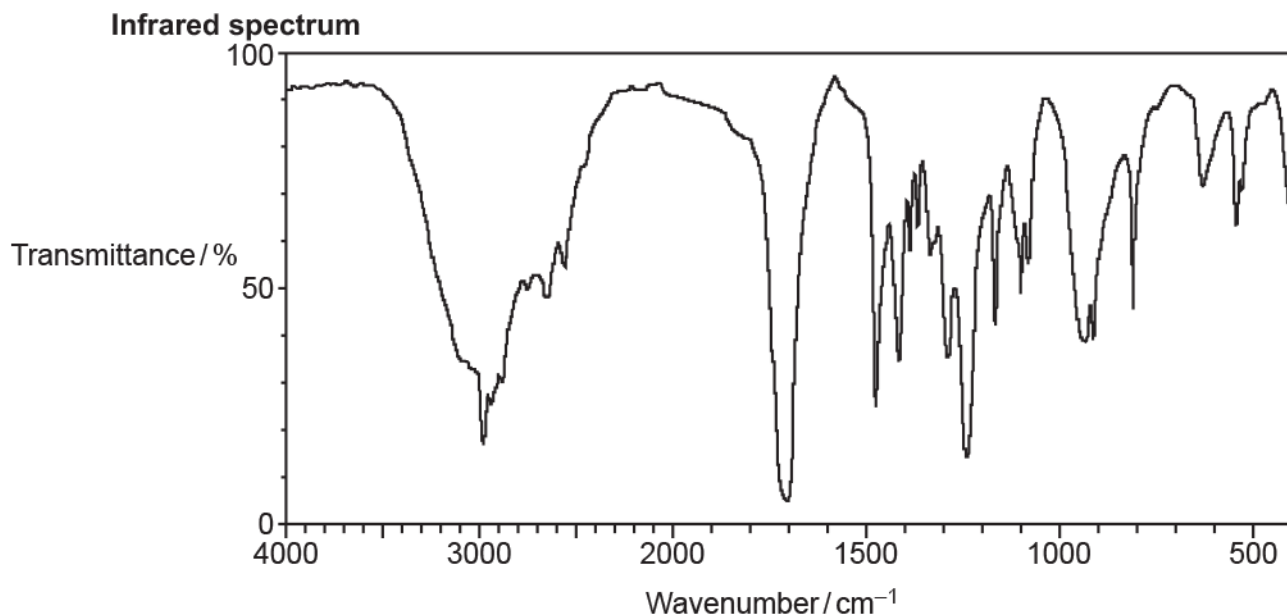
[2]

(b) Maleic acid can be made from 'maleic anhydride', $C_4H_2O_3$.

Suggest a skeletal formula for maleic anhydride.

[1]

(c) * Compound A has spectra as shown below.



You may do working on this page but it will not be marked

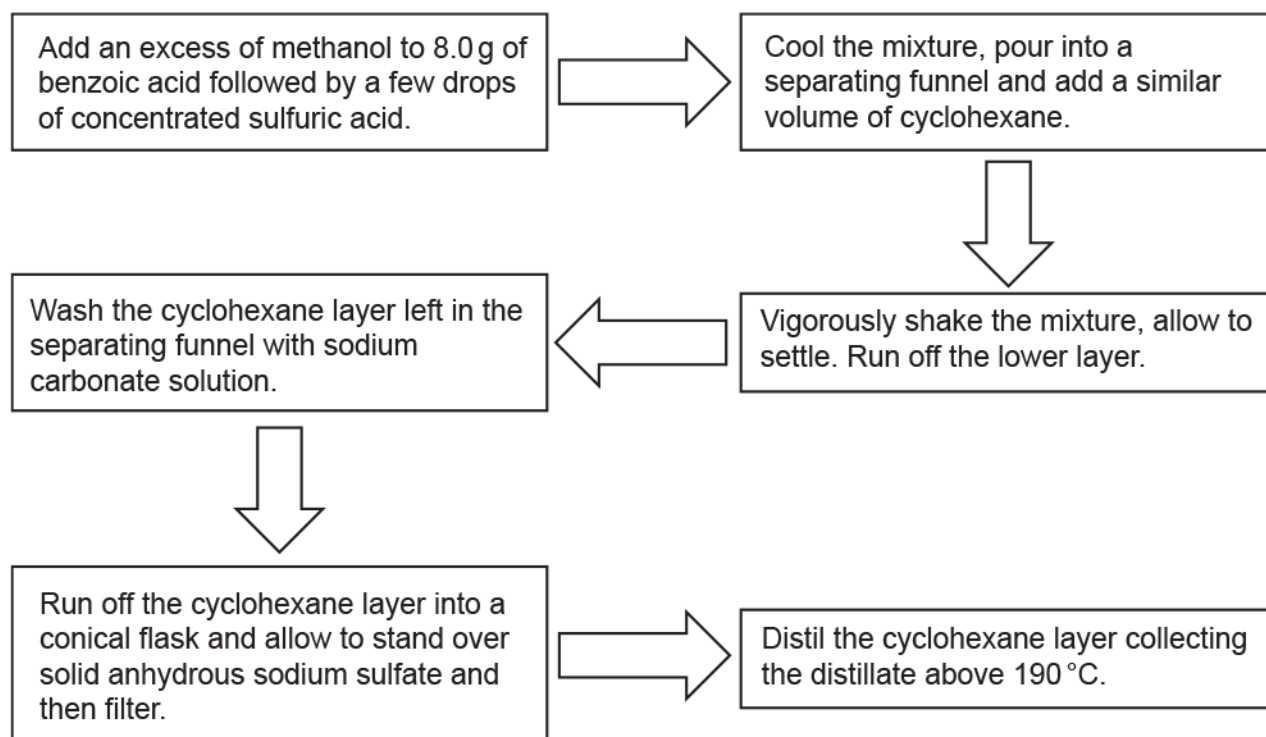
Compound **A** has four carbon atoms in its molecule.

Identify compound **A**, giving evidence from each spectrum.

[6]

49(a) Methyl benzoate is a liquid at room temperature and has a boiling point of 200 °C.

The steps in a procedure for preparing and purifying the simple ester, methyl benzoate, are shown in the flow chart.



Give the reasons for the following experimental procedures in the flow chart:

(i) adding cyclohexane

----- [1]

(ii) adding sodium carbonate solution

----- [1]

(iii) standing the cyclohexane layer over solid anhydrous sodium sulfate

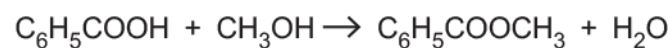
----- [1]

(iv) collecting the distillate above 190 °C

----- [1]

(b) A student followed the procedure in the flow chart and obtained 5.46 g of methyl benzoate.

The equation for the preparation is:



benzoic acid methanol methyl benzoate

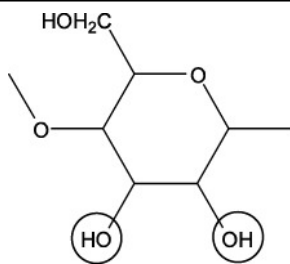
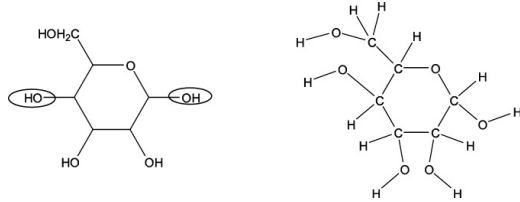
Calculate the percentage yield of methyl benzoate.

Give your answer to an **appropriate** number of significant figures.

percentage yield = ... % [4]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance						
1		i	ether ✓	1	Examiner's Comments This was well answered, though some circled the primary alcohol or just the C to which a secondary hydroxyl was attached.						
		ii	 either or both circled as above ✓	1	ALLOW if adjacent C is also circled Examiner's Comments This was well answered, though some circled the primary alcohol or just the C to which a secondary hydroxyl was attached.						
		iii	 both circled OH groups present ✓ full structural formula correct ✓	2	Examiner's Comments Many gave the skeletal formula in (iii) rather than full structural, whilst those who attempted the full structure omitted one or more H atoms from the ring and usually drew -OH instead of -O-H.						
			Total	4							
2	a		<table><tr><th>test</th><th>observations</th></tr><tr><td>For C (add neutral) iron(III) chloride (solution) / FeCl₃ ✓</td><td>purple colour formed ✓</td></tr><tr><td>For D (add) Na₂CO₃ (s) or (aq) ✓</td><td>solution / mixture fizzes / bubbles / effervesces / (colourless) gas given off ✓</td></tr></table>	test	observations	For C (add neutral) iron(III) chloride (solution) / FeCl ₃ ✓	purple colour formed ✓	For D (add) Na ₂ CO ₃ (s) or (aq) ✓	solution / mixture fizzes / bubbles / effervesces / (colourless) gas given off ✓	4	DO NOT ALLOW iron chloride ALLOW violet NOT blue or red ALLOW NaHCO ₃ / K for Na / Ca CO ₃ / MgCO ₃ / carbonate Examiner's Comments Most got full marks here, but some used dichromate or sodium hydroxide for the acid in the test for D. Some confused the terms observation and conclusion, stating that CO ₂ was given off.
test	observations										
For C (add neutral) iron(III) chloride (solution) / FeCl ₃ ✓	purple colour formed ✓										
For D (add) Na ₂ CO ₃ (s) or (aq) ✓	solution / mixture fizzes / bubbles / effervesces / (colourless) gas given off ✓										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	1 mark for each correct structure ✓✓	2	Any clear structure acceptable ALLOW NH_3Cl/. NH_3^+ DO NOT ALLOW an OH group to be bonded to the ring via -HO Examiner's Comments Generally poorly done with many not realising this was an hydrolysis reaction which resulted in a variety of ethanoylated products being drawn. More candidates correctly drew the 2-hydroxybenzoic acid than the amine, which was usually left unprotonated.

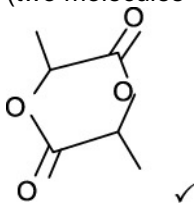
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	draw pencil-line near bottom of plate / sheet ✓ place 1 drop (or similar word) of mixture AND a drop of each of the 2 compounds (on the line) AW ✓ place plate in solvent, line above solvent level AND add lid / cover ✓ when solvent nears top of plate AW, remove / dry plate ✓ locate spots with / expose to UV light / iodine ✓ compare heights / position of spots from mixture with the two compounds AW OR calculate / measure / determine R_f values of spots and compare with those of the two compounds AW ✓	6	please annotate marks given with ticks ALL marking points may be gained from labelled diagram(s) ‘near bottom’ may be implied by what follows DO NOT ALLOW paper for plate / sheet BUT ecf for further use ALLOW draw base-line with pencil any other named locating agent is a CON DO NOT ALLOW ‘locating agent’ alone DO NOT ALLOW vague statements about comparing spots, MUST refer to positions DO NOT ALLOW vague statements about R_f values <i>e.g.</i> R_f values will identify compounds MUST indicate that spot heights or R_f values have been measured AND compared Examiner's Comments The students who had worked hard on their revision did very well here with many gaining full marks. Some ninhydrins but not many, some used chromatography paper, others only spotted the mixture on to the plate and a few lost the last mark for not measuring and comparing R_f values.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3		i	(primary) amine ✓	1	ALLOW amino Examiner's Comments A large number could name the amine group correctly
		ii	benzenediazonium chloride ✓	1	ALLOW benzene diazonium chloride ALLOW diazonium chloride / (benzene)diazonium ion / salt IGNORE formulae Examiner's Comments Fewer candidates could name benzene diazonium chloride or a significant part of this name.
		iii	coupling ✓	1	ALLOW electrophilic substitution IGNORE 'synthesis', '(di)azo' Examiner's Comments The name 'coupling' was known by most candidates.
		iv	react with (hydrogen)carbonates / formulae ✓ effervescence / fizz / give gas / give CO ₂ ✓	2	ALLOW any carbonate (eg CaCO₃) <i>second mark depends on first</i> IGNORE other products of reaction or other correct reactions Examiner's Comments Relatively few candidates understood that they had to describe the reaction of acids with carbonates to form carbon dioxide. A large number answered in terms of delocalisation of the anion.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4		i	$C_7H_{11}COOH + ROH \rightleftharpoons C_7H_{11}COOR + H_2O$ Equilibrium sign ✓ equation (with equm sign or arrow) ✓	2	ALLOW any unambiguous structural formulae ALLOW $CH_3CHCHCH_2CHCHCH_2COOH + ROH \rightleftharpoons CH_3CHCHCH_2CHCHCH_2COOR + H_2O$ IGNORE errors in the chain as long as there are seven carbon atoms shown in the chain. Mark separately ALLOW reaction with ethanol (CH_3CH_2OH or C_2H_5OH) Examiner's Comments Most candidates could write this equation, with a correct equilibrium sign. The commonest errors were the omission of the equilibrium sign and the omission of water as a product.
		ii	catalyst ✓ removes / reacts with / lowers concentration of water ✓	2	ALLOW 'provides H^+ ions' / 'protonates' as <i>alternative</i> to 'catalyst' but only one can score. Examiner's Comments Most knew that the sulfuric acid was a catalyst but only a few seemed aware of its function of absorbing water and moving the position of equilibrium to the right.
			Total	4	
5			OH / alcohol group reacts with acid / COOH group OR two molecules react / condense to lose (two molecules of) water ✓ 	2	ALLOW any correct representation of structure Examiner's Comments This was another tough question that was tackled well by many candidates. Most realised that lactic acid had both an acidic and an alcohol group and many could also draw the cyclic ester correctly. Relatively few ignored the molecular formula and drew an internal ester of lactic acid.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6			peak around 3500 / 3600 / in range 3200-3600 indicates O-H / hydroxyl bond in alcohol ✓ so cellulose diethanoate since only 2 of the 3 OH groups in repeating unit of cellulose have reacted / one OH / no OH groups in cellulose triethanoate ora AW ✓	2	IGNORE references to no O-H peak in range 2500-3200 MUST relate OH group to answer DO NOT AWARD this mark if a COOH group is also given as present Examiner's Comments A few students answered this perfectly, recognising the difference in structure of the two compounds and therefore identifying the correct one from the correct peak signifying the OH group. However, the vast majority of students said there was no peak at 3500-3600 cm⁻¹. Some, including able candidates, even marked it on the diagram and then denied it was there. Somehow the words 'broad' and 'strong' seem to have been picked up by candidates as all-important, so they then decided to ignore any smaller peaks. The fact that the wavenumber scale is not linear and peaks with similar widths at different ends means that in reality they are anything but. Many argued on the basis of C=O absorptions suggesting that the high intensity of the peak indicated three ethanoate groups.
			Total	2	
7			A	1	
			Total	1	
8			B	1	
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
9	<i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Analyses information AND spectral data to provide evidence to support the correct and full identification of all compounds A, B, C and D. Evidence from reactions of A AND no reaction of B with Tollens' reagent or NaOH AND MS spectrum AND ^{13}C NMR spectrum. <i>The information and evidence used is relevant and fully supports the identification. The answer is clear and logically structured.</i> Level 2 (3–4 marks) Analyses information AND data to provide evidence to support the partial identification of compound A as a secondary alcohol, B as a ketone and C and D as alkenes. Evidence from reactions of A AND no reaction of B with Tollens' reagent or NaOH AND EITHER MS spectrum OR ^{13}C NMR spectrum <i>The information and evidence used is in the most part relevant and supports the identification. The answer is presented with some structure.</i> Level 1 (1–2 marks) Analyses information OR data to provide evidence allowing partial identification of the compounds A AND B OR C AND D using reactions of A OR no reaction of B with Tollens' reagent or NaOH OR using information from MS Spectrum OR ^{13}C NMR spectrum	6	Indicative scientific points may include: Full identification Compound A is $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$ Compound B is $\text{CH}_3\text{CH}_2\text{COCH}_3$ Compounds C & D are $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$ and $\text{CH}_3\text{CH}=\text{CHCH}_3$ Evidence from spectral data MS Spectrum: $M_r(\text{C}_x\text{H}_y\text{O}) = 74$ $M_r(\text{C}_x\text{H}_y) 74 - 16 = 58$ so $x = 4$ and $y = 10$. ^{13}C NMR: 2 from 4 carbon environments - no $\text{C}=\text{O}$ or $\text{C}=\text{C}$ $\text{C}-\text{O}$ (and $\text{C}-\text{C}$) present. Evidence from the Reactions: A is alcohol from formula plus $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ reaction - Heating A with Al_2O_3 results in elimination of water from A forms 2 different alkenes, C and D - Thus A secondary and B a ketone. A reacts with $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ when heated → B is aldehyde, ketone or carboxylic acid - No reaction with Tollens' → B is NOT an aldehyde - No reaction with NaOH → B is NOT a carboxylic acid - Conclusion: B is a ketone AND A a secondary alcohol. For Level 1: partial identification of A required. May be supplemented by partial identification of B OR partial identification of C and D.

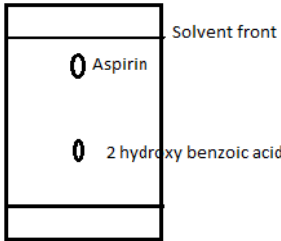
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>The information and evidence is used to make a partial identification of A AND B OR C and D. The evidence chosen does not fully support the identification and is not presented in a logical order.</i> 0 marks No response or no response worthy of credit.		
			Total	6	

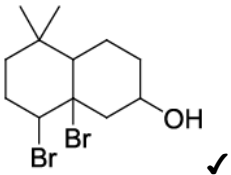
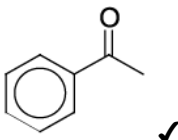
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
10	a	<i>*Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Fully describes the differences between the two compounds in detail with both ring descriptions correct. Describes at least three reactions with examples and equations. <i>The full description is detailed and correct. There is a clear and logical structure. The reactions are relevant and fully supported with examples and equations. Demonstrates a clear and confident knowledge of relevant technical language (names of compounds, 'substitution', 'elimination', 'delocalisation').</i> Level 2 (3–4 marks) Describes the differences between the two compounds in detail including electron delocalisation in phenol. Describes at least two reactions with equations but not necessarily showing reactions for both structures. <i>The description is detailed and is presented with some structure. The reactions are in the most part relevant and supported by equations. Demonstrates ability to answer question with some indications of a sound grasp of technical language.</i> Level 1 (1–2 marks) Identifies the differences between the two structures mentioning phenol and alcohol. Describes at least two reactions. <i>The description is basic and communicated in an unstructured way. The reactions are relevant but lack detail. Demonstrates a basic grasp of relevant technical language.</i>	6	Indicative scientific points may include: Ring structures: • saturated ring of 6 carbons in alcohol • unsaturated ring of 6 carbons in phenol with 6 delocalised electrons Reactions of –OH group: • acidic in phenol neutral in alcohol e.g. with alkalis* (NOT with carbonates) • nucleophilic substitution in alcohol e.g. with halide* • elimination in alcohol not in phenol e.g. form alkenes* with Al_2O_3 / H_2SO_4 • phenols give purple colour with $FeCl_3$ • phenols will not react with carboxylic acids but alcohols will*. * an equation can be written here If other correct reactions are given which are NOT different between the two compounds mark lower at each level

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			0 marks No response or no response worthy of credit.		
	b		Gas-liquid chromatography OR Thin layer chromatography OR paper chromatography ✓	1	ALLOW glc or tlc
			Total	7	
11			A	1	
			Total	1	
12	a		$\text{C}_6\text{H}_4(\text{OH})\text{CO}_2\text{H} + (\text{CH}_3\text{CO})_2\text{O} \rightarrow \text{C}_6\text{H}_4\text{CO}_2\text{H}(\text{OCOCH}_3) + \text{CH}_3\text{COOH}$ Ethanoic anhydride AND aspirin ✓ Ethanoic acid product ✓	2	ALLOW any unambiguous formulae and a mixture of displayed and structural formulae
	b		Sketch and label 2 spots with: aspirin more than half-way up salicylic acid less than half-way up 	1	start line and solvent front do not have to be marked.
	c		Aspirin must have a greater solubility at higher temperature SO it will crystallise on cooling AW✓	1	
			Total	4	
13			$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{COOH}$ ✓ internal ester formation (AW) ✓	2	ALLOW any unambiguous representation of structure
			Total	2	

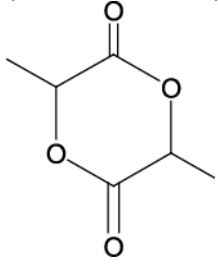
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14	a	i		1	ALLOW any unambiguous formula clearly displaying the structure of the compound.
		ii	11 ✓	1	
		iii	two ✓ (because ambrinol has two) asymmetric carbon atoms / carbon atoms surrounded by 4 different groups ✓	2	
		iv	yes, because same bonds ✓ hence same vibrations ✓	2	ALLOW: no, based on analogy with named compound ✓ (e.g. carvone) for which enantiomers smell different ✓
	b		vanillin and guaiacol are phenols ✓ purple colour with FeCl_3 ✓ benzaldehyde and vanillin are aldehydes ✓ acid dichromate goes green OR Tollens' reagent OR AgNO_3 and NH_3 ... give silver (mirror) OR Fehlings solution gives red precipitate ✓	4	
	c		IR spectrum that shows how bonds vibrate ✓ Shows similarity between spectra of vanillin and combination of guaiacol and benzaldehyde (AW) ✓ C-H in arenes ✓	3	
	d	i	(atoms with) same atomic number AND different mass number ✓ 1 and 7 ✓	2	must mention both terms
		ii	12.01 ✓	1	
		iii	 all hydrogen atoms replaced with deuterium atoms ✓	2	Correct skeletal formula required. ALLOW 'H'/'proton' for 'hydrogen atom' and 'D' for deuterium atom To score, answer must state that all the atoms are replaced.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	<i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Supporting evidence for Turin's theory AND evidence to discredit the lock and key theory have been correctly identified. There is a clear discussion related to both theories. <i>The evidence selected is relevant and substantiated. The discussion shows a well-developed line of reasoning for the choices of evidence, which is clear and logically structured.</i> <i>Candidate demonstrates a clear and confident knowledge of relevant technical language (names of compounds, 'deuterated', 'vibrate').</i> Level 2 (3–4 marks) Supporting evidence for Turin's theory AND evidence to discredit lock and key theory have been correctly identified although there is a limited attempt to discuss them. <i>The evidence selected is in the most-part relevant.</i> <i>The discussion has some structure but is limited in scope.</i> <i>Candidate demonstrates a sound grasp of technical language (one spelling error).</i> Level 1 (1–2 marks) Evidence for Turin's theory has been identified OR Evidence against lock and key theory <i>The information is supported by limited evidence and the relationship to the evidence may not be clear. The discussion is basic and communicated in an unstructured way.</i> <i>Candidate demonstrates a basic grasp of</i>	6	Indicative scientific points may include: Statements to support Turin's theory • deuterated acetophenone smells different (from non-deuterated form) • deuterated benzaldehyde smells different (from non-deuterated form) • because H and D have different masses and hence C–D and C–H vibrate differently • C¹² and C¹³ exchange does not affect smell, since masses only differ slightly • structures of deuterated acetophenone and benzaldehyde given. Statements to discredit Lock and Key • since structures are similar, lock and key theory would not predict difference (AW). • structurally related molecules can smell utterly different.

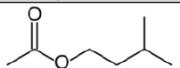
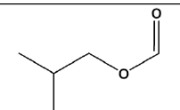
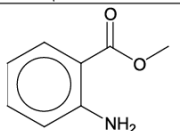
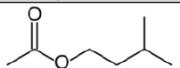
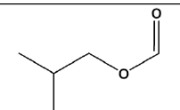
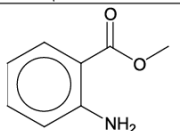
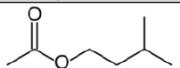
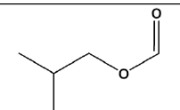
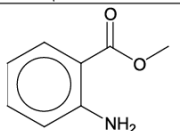
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>relevant technical language (several spelling errors).</i> 0 marks No response or no response worthy of credit.		
			Total	24	
15			OH / alcohol group reacts with COOH / acid group ✓ OR two molecules react / condense to lose (two molecules of) water ✓  ✓	2	ALLOW any correct representation of structure.
			Total	2	
16	a	i	Ethane-1,2-diol	1	ALLOW ethanediol
		ii	OH group bonded to C with 2H or 1C	1	IGNORE 'it' for OH group but ALLOW 'alcohol group' for OH group
	b	i	aldehyde	1	
		ii	EITHER Warm with Tollens' reagent / silver mirror ✓ OR Heat with Fehling's solution / Red ppt ✓	2	ALLOW chemical descriptions of Tollens' or Fehling's. Second mark depends on reagent being identified
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17	a	i	Boiling a mixture ✓ AND condensing / cooling the vapour to return it to the flask ✓	2	
		ii	Diagram showing a funnel with a filter paper above a perforated plate ✓ fitting into a flask or tube with a side arm ✓ indication of removal of air from the flask through the side arm ✓	3	ALLOW water flow through a tube connected to the side arm
		iii	Dissolve crystals in minimum of hot water ✓ Cool solution (to produce crystals) ✓ Filter off crystals AND wash with cold solvent ✓ Hexane-1, 6-dioic acid is more soluble in hot water than in cold water ✓	4	'Minimum' amount of water MUST be stated
		iv	FIRST CHECK THE ANSWER ON THE ANSWER LINE yield = 31% award 2 marks M_r (repeat unit) = 226 $n(\text{nylon-6, 6}) = 2.0 / 226 = 0.00885 \text{ (mol)}$ ✓ $n(\text{hexane-1, 6-dioic acid}) = 0.40 / 146 = 0.00274 \text{ (mol)}$ $0.00274 / 0.00885 \times 100 = 31 \text{ (\%)}$ OR theoretical yield of acid = $0.00885 \times 146 = 1.29 \text{ g}$ $\text{yield} = \frac{0.40}{1.29} \times 100 = 31 \text{ (\%)} \checkmark$	2	ALLOW ECF from first marking point ALLOW 31.0
	b		('Fishy smell' caused by) $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$ ✓	1	
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance															
18	a	i	speeds up reaction / catalyst ✓	1	IGNORE references to sulfuric acid removing water produced															
		ii	neutralises excess acid (so easier to smell ester) AND fizzing / effervescence / bubbling ✓	1																
	b		<table><tr><th>Alcohol</th><th>Carboxylic acid</th><th>Structure of Ester</th></tr><tr><td>pentan-1-ol</td><td>ethanoic acid</td><td></td></tr><tr><td>3-methylbutan-1-ol</td><td>ethanoic acid</td><td></td></tr><tr><td>2-methylpropan-1-ol</td><td>methanoic acid</td><td></td></tr><tr><td>methanol</td><td>anthranilic acid</td><td></td></tr></table> ✓ ✓ ✓	Alcohol	Carboxylic acid	Structure of Ester	pentan-1-ol	ethanoic acid		3-methylbutan-1-ol	ethanoic acid		2-methylpropan-1-ol	methanoic acid		methanol	anthranilic acid		3	one mark for each ALLOW any unambiguous representations of structures
Alcohol	Carboxylic acid	Structure of Ester																		
pentan-1-ol	ethanoic acid																			
3-methylbutan-1-ol	ethanoic acid																			
2-methylpropan-1-ol	methanoic acid																			
methanol	anthranilic acid																			
	c	i	removes water / drying agent ✓	1																

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question. Level 3: 5–6 marks Identifies key absorptions unique to ester, justifying by C13 NMR AND IR spectra. States both wavenumber and relevant absorption for IR Recognises any difference in C13 NMR AND IR spectra for BOTH alcohol and acid spectra <i>The ideas are logical and well-structured providing significant clarity in the communication of the science</i> Level 2: 3–4 marks Identifies key absorptions unique to ester, justifying by C13 NMR AND IR spectrum OR absence of features from acid and alcohol. <i>There is partial structuring of the ideas with the communication of the science generally clear.</i> Level 1: 1–2 marks Identifies key absorptions unique to ester, justifying by C13 NMR OR IR spectrum. Recognises any difference in EITHER spectra for EITHER acid or alcohol <i>The ideas expressed are logical but limit the communication of the science.</i> Level 0: (no marks) <i>No response or no response worthy of credit.</i>	6	Expected chemical points: Ester <i>C-13 spectrum_ (at least 2 from:)</i> • 4C environments suggest ester present; • ca 160 shift suggests C=O • 70 shift suggests C-O <i>IR spectrum_ (at least 2 from:)</i> • no OH absorption • C=O at around 1750 • C-O at around 1250 Alcohol <i>C-13 spectrum</i> • 3C environments • one at δ 50–70 (C-O) <i>IR spectrum</i> • OH absorption in region 3200–3600 • no C=O stretch at 1750 Carboxylic Acid <i>C-13 spectrum</i> • only 1C environment • at δ 160–200 (C=O) <i>IR spectrum</i> • OH absorption in region 2500–3300 All three molecules • C-H at 2900 stretch in IR spectra NB
			Total	12	

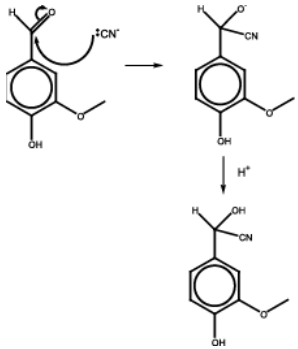
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a	i	aldehyde / carbonyl ether / methoxy phenol / hydroxyl ALL three correct ✓ ✓ TWO correct out of 2 or 3 answers ✓	2	any answer with 4 groups listed deduct 1 mark more than 4 groups award no marks DO NOT ALLOW hydroxide / hydroxy ALLOW phenolic hydroxy Examiner's Comments Answers usually included 3 groups but some candidates perhaps seeing two marks thought two would do. Occasionally the aldehyde group was called a carboxyl.
		ii	sulfuric acid AND potassium / sodium dichromate(VI) ✓	1	ALLOW without oxidation state, but if given must be correct ALLOW 'acidified (potassium) dichromate' ALLOW sulfuric acid as the only named acid IGNORE concentration of acid Examiner's Comments Well known, only a few managed to get the oxidation state of chromium wrong.
	b	i	1705 indicates C=O in ketone /or carboxylic acid thus apocynin ✓ 3310 indicates OH in phenol ✓ 3010 indicates CH in arene / benzene ring AND 2930 indicates CH in alkane ✓	3	ALLOW since NOT 1720-1700 it is not an aldehyde so must be apocynin IGNORE alcohol IGNORE alkene Examiner's Comments Generally, well done, the usual error was not to mention either the bond responsible for the peak or what group it was from. If the candidate had identified carboxylic acid in (a)(i) then it often reappeared here and vanillin was chosen as the white powder.

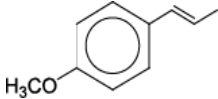
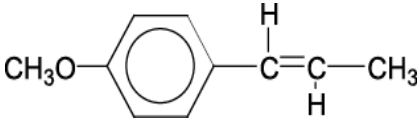
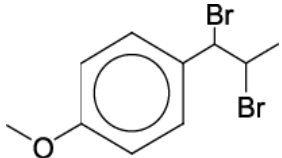
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	1. compare the M^+ / molecular (ion) peaks (AW) ✓ molecular ion peak of apocynin will be at a larger m/z by 14 or molecular ion peak's m/z is in vanillin at 152, in apocynin at 166 ✓ 2. look for peak at m/z 43 or 29✓ due to $COCH_3^+$ / $COCH_3$ group from apocynin or due to CHO^+/CHO from vanillin ✓	2 from	Comparison may be assumed by stating the two values ALLOW peak in vanillin at molecular ion peak's m/z -1 (loss of aldehyde H) indicates vanillin IGNORE loss of methyl group / peak at $m/z = 15$ Examiner's Comments What the nature of the peaks are and their labels is not commonly understood although candidates do recognise the basics of mass spectrometry. The main weakness was the inability to determine the molecular formula from the structures given and hence the expected molecular mass.
		iii	dissolve in a minimum amount of hot / warm <u>water</u> AW ✓ QWC mark leave to crystallise / crystals to form and filter ✓ wash crystals with (a little cold) water / solvent and dry ✓	3	ALLOW formation of saturated solution spelling of (re)crystallise / recrystallisation / crystals MUST BE CORRECT at least once ALLOW crystallisation / crystallize / crystallization Examiner's Comments Again another question more care in reading the rubric would have benefited candidates. Many candidates started by describing the characteristics of a good solvent for recrystallisation but failed to apply that to the properties of water with respect to dissolving the material at high and low temperatures. A common error was not to filter to collect the recrystallised apocynin and / or not managing to spell crystals etc. correctly.

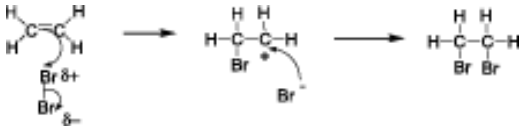
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	C		 2 curly arrows (1 from lone pair on C of CN^-) AND bond polarity correct on at least one atom of C=O ($\delta^+ \text{C}=\text{O} \delta^-$) ✓ correct formula for cyanide including lone pair on C and -ve charge on CN ✓ intermediate correct ✓ addition of H^+ AND final product correct ✓	4	IGNORE any curly arrows and lone pairs involving formation of the $-\text{OH}$ group IGNORE curly arrow from / to H^+ Examiner's Comments Usual errors were not drawing the intermediate, not knowing the final structure around the carbonyl and the formula of the cyanide ion. The use of curly arrows was one of the better aspects of this question. Some decided that nucleophilic attack took place at the phenolic carbon.
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20	a	i	C ₁₀ H ₁₂ O	1	ALLOW elements in any order Examiner's Comments Most candidates wrote the correct C₁₀H₁₂O but there were some errors.
		ii	ether	1	ALLOW methoxy Examiner's Comments Many candidates wrote 'ether' but some gave 'alcohol' and others did not read the need to name a saturated group and said 'alkene'.
		iii		1	ALLOW any appropriate structural formula or mixture of types of formula. ALLOW  IGNORE small errors in structure if trans is clear Examiner's Comments Most represented the <i>E</i> isomer correctly using a structural, rather than a skeletal formula.
	b			1	must be skeletal (including ether) ALLOW both bromines on same side Examiner's Comments This was usually correct, including the ether group.

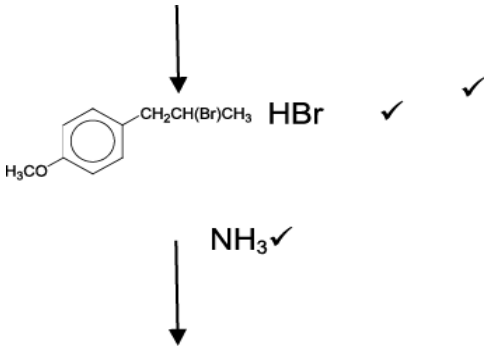
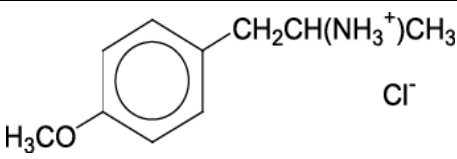
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	 bromine attacking C=C including curly arrow and curly arrow and dipole on bromine✓ intermediate formula (could be cyclic)✓ Br⁻ attacking and formula of product✓	3	curly arrows must start (when projected back) on bond (or – [or lone pair if drawn] on Br⁻) and finish pointing at atoms shown or at the new bond to be formed. IGNORE half arrows. IGNORE partial charges on atoms (or bond) of C=C ALLOW last mark if there is no charge on carbocation Examiner's Comments Some candidates produced very polished mechanisms. Others were not careful enough as to where their curly arrows started. They must start either from a bond or a lone pair (the negative charge on the bromide ion was accepted). The first mark was the hardest to score with some drawing arrows to the alkene from the bromine.
		ii	(First) attack/attraction (AW) is by an electrophile (Br₂) OR by Br⁺/Br^{δ+}✓ (Then) H₂O/water can attack (AW) (carbocation)/ can act as nucleophile AW OR water is not an electrophile✓	2	ALLOW 'OH' for 'water' but not OH⁻ Examiner's Comments A few candidates got the idea that the bromine electrophile had to attack first followed by the water nucleophile. However, many failed to gain the second mark by referring to hydroxide ions rather than water molecules or hydroxyl groups.

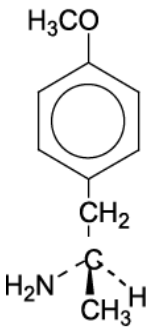
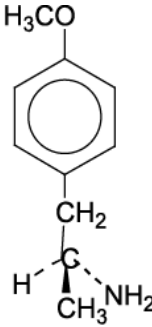
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		1. Hydrogen bonds are formed between lone pair on O✓ 2. and $H^{\delta+}$/ H polarised by O-H/ partially(AW) positive hydrogen/H✓ 3. Anethole hydrogen bonds (with water)✓ 4. hydrogen bonds in water are broken 5. hydrogen bonds in water are greater/stronger than imb between anethole and water OR more hydrogen bonds broken than made OR more energy is needed to break bonds than is released in making them OR anethole only forms one/two/few hydrogen bonds OR rest of anethole can't hydrogen bond (ORA)/ forms id-id✓	5	ALLOW 1., 2. and 3. from diagram reference to hydrogens in anethole forming H-bonds CONs 2. (1. and 2. can be scored separately) 3. and 4. can be scored with some of the alternatives for 5. 5. ALLOW – for dissolving to occur strength/energy of bonds broken must (roughly) equal strength/energy of bonds made IGNORE other attempts at this point if one is correct Examiner's Comments Scoring was high here which is encouraging. Some glossed over the idea of a lone pair on oxygen attracting a partially positive hydrogen. Most realised that anethole would hydrogen bond with water as it had an ether oxygen. Many scored for saying 'few hydrogen bonds' or addressing the partial solubility in a myriad other acceptable ways. The mark least scored was for saying that hydrogen bonds in water were broken.

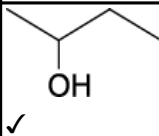
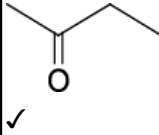
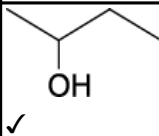
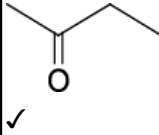
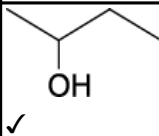
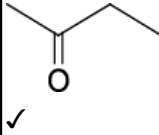
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e	i	 <chem>COc1ccc(CC(Br)C)cc1</chem> $\xrightarrow{\text{HBr}}$ <chem>COc1ccc(CC(C)(Br)C)cc1</chem> $\xrightarrow{\text{NH}_3}$ <chem>COc1ccc(CC(C)N)cc1</chem>	3	ALLOW any unambiguous formula for intermediate ALLOW 'NaBr/H⁺' for 'HBr' Can be names of reagents IGNORE state symbols on reagents ALLOW substitution of HCl/hydrochloric acid with chlorine on intermediate Mark all points separately. BUT For 1 mark, allow Br₂ or H₂O for first reagent followed by corresponding product in intermediate box. Examiner's Comments Some candidates realised that the bromo derivative was the intermediate and used HBr to form it and ammonia to react with it. Many candidates benefitted from the decision to mark the three points separately, particularly the ammonia mark.
		ii		1	ALLOW 'NH₃Cl' instead of ions but not 'NH₃-Cl' ALLOW N⁺H₃ and (NH₃)⁺ ALLOW without the chloride Examiner's Comments Many candidates correctly protonated the amine group but some added chlorine atoms to the chain or to the ring.
		iii	Drug X has C/chiral centre with four different groups/ asymmetric C✓ indication of which C and which four groups✓ no equivalent C in anethole (AW)✓	3	second marking point can be scored from e(iv) if not scored here ALLOW 'nonsuperimposable mirror image' as alternative to first mpt Examiner's Comments There was high scoring here, the commonest error being to omit 'anethole doesn't have a carbon attached to four different groups'. Diagrams from 1eiv were allowed in awarding the 'which C and which four groups' mark which allowed a lot more candidates to gain marks.

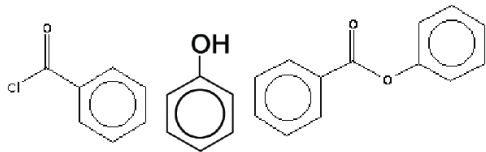
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	  one correct 3d structure✓ mirror image✓	2	ALLOW  instead of ____. ALLOW any unambiguous representation of the 3d structures, but straight lines must not be at 180°. (allow mirror image by ecf) IGNORE incorrect groups when marking mirror image IGNORE non-reflection of NH₂ etc IGNORE bonds to hydrogens rather than C/N ALLOW correct enantiomers even if not shown as mirror images ALLOW any indication of organic group even if slightly erroneous and ambiguous attachments Examiner's Comments Most were able to draw the correct diagrams, though some used the wrong structure for X. Candidates must realise that two 'lines' opposite each other do not represent a three-dimensional structure.
		v	peak/trough at 3300 - 3500 (cm⁻¹)/ one value in the range caused by N-H/NH₂/amine✓ no peak at 1620 – 1680/ one value in the range caused by C=C/ alkene✓	2	Both range and bond/group needed in each case. Award one mark for both ranges without bonds/groups or vice versa Examiner's Comments Many either quoted the absence of a C=C bond or the presence of an N-H bond; some gave both, as required.
			Total	25	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance									
21	a		tertiary AND OH group attached to C with no H/ 3 Cs	1	IGNORE 'it' for 'OH group'									
	b		<table border="1"><thead><tr><th></th><th>Skeletal formula</th><th>Name</th></tr></thead><tbody><tr><td>A</td><td></td><td>butan-2-ol ✓</td></tr><tr><td>B</td><td></td><td>butanone ✓</td></tr></tbody></table>		Skeletal formula	Name	A		butan-2-ol ✓	B		butanone ✓	4	Names must match structures ALLOW ecf for B as the oxidation product of A ALLOW butan-2-one
	Skeletal formula	Name												
A		butan-2-ol ✓												
B		butanone ✓												
			Total	5										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22	a			1	ALLOW any recognisable structure ALLOW Kekule structures
	b	i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 50.5(0) – 51.0 (%) award three marks Correct use of masses from table for both phenol used (5.02 g) and phenyl benzoate formed (5.34 g) ✓ Correct calculation for moles used(0.0534) and hence mass for 100% conversion (moles × 198) = 10.57 ✓ Correct % yield calculation $5.34 \div 10.57 \times 100 = 50.50(\%)$ ✓	3	ALLOW ecf's after first step ALLOW three or more sf ALLOW moles of phenol used (0.0534) and moles of phenyl benzoate formed = $5.34/198$ OR 0.270 % yield (= $0.0270/0.0534 \times 100$) = 50.56% evaluated
		ii	ANY one of: Reaction did not go to completion/incomplete reaction Loss of solid in transfer between apparatus AW ✓	1	ALLOW side reactions occur/ by-products formed ALLOW specific side reactions e.g. benzoyl chloride formed benzoic acid in the water solvent/ benzoate ions in the alkaline conditions
		iii	Melts over temperature range/Lower mp indicates presence of impurities / very close to literature value so level of impurities small AW ✓	1	ALLOW statements such as 'sharpness (small range) suggests near purity'

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Description and detailed explanation of most stages in the recrystallization. AND Specifies some of the desirable properties of a suitable solvent. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Description of most stages in the recrystallisation with a limited explanation of the steps. AND Specifies some of the desirable properties of a suitable solvent. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description of stages in the recrystallisation with detailed explanation of some of the stages. AND Specifies some of the desirable properties of a suitable solvent. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	6	Indicative scientific points may include: Description of steps in recrystallisation • dissolves organic solid in a minimum volume of (suitable) hot solvent • filters hot solution • cools solution • re-filters • allows crystals to dry Explanation of steps • vacuum filtration used so solution remains hot • insoluble impurities removed • crystals formed when solution cools vacuum filtered again; soluble impurities go through in solution • washed with cold solvent (minimises further loss of product but ensures any soluble impurities left washed through) • Crystals left to either air dry or in oven at a temperature lower than mp of solid Desirable properties of a suitable solvent • solid should be very soluble in solvent chosen at high temps, but not very soluble at low temps • soluble impurities remain in solution even at low temps
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23			A	1	
			Total	1	
24			C	1	
			Total	1	

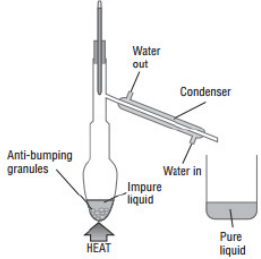
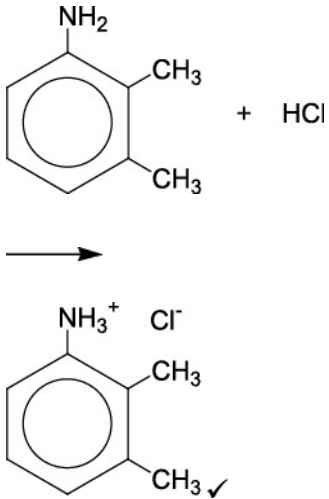
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
25	a		Titrate the equilibrium mixture with alkali/NaOH of known concentration (to find total moles of acid) ✓ Subtract moles of (H ₂ SO ₄) catalyst ✓	2																					
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 3.61 award 4 marks <table><tr><th>Sub-stance</th><th>Mass at start</th><th>Amount present at the start</th><th>Amount present at equilibrium</th></tr><tr><td>ethanol</td><td>15.8</td><td>15.8/46 (= 0.343)</td><td>(0.343 – [0.35 – 0.123]) = 0.116</td></tr><tr><td>ethanoic acid</td><td>21.0</td><td>21.0/60 (= 0.35(0))</td><td>0.123</td></tr><tr><td>ethyl ethan- oate</td><td>0</td><td>0</td><td>[0.35–0.123 =] 0.227</td></tr><tr><td>Water</td><td>0</td><td>0</td><td>0.227</td></tr></table> One mark for both amounts at start ✓ One mark for amount of ethanol at equilibrium ✓ One mark for amounts of ester and water at equilibrium ✓ $K_c = 0.227^2 / (0.123 \times 0.116) = 3.61$ ✓	Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium	ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116	ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123	ethyl ethan- oate	0	0	[0.35–0.123 =] 0.227	Water	0	0	0.227	4	ALLOW ecf throughout ALLOW other answers (to 2 or more sf) by using various rounding during calculation.
Sub-stance	Mass at start	Amount present at the start	Amount present at equilibrium																						
ethanol	15.8	15.8/46 (= 0.343)	(0.343 – [0.35 – 0.123]) = 0.116																						
ethanoic acid	21.0	21.0/60 (= 0.35(0))	0.123																						
ethyl ethan- oate	0	0	[0.35–0.123 =] 0.227																						
Water	0	0	0.227																						
	c		H CH₃ —C— C— H CO OCH₃ ✓	1	ALLOW any unambiguous structure IGNORE brackets or ‘n’																				
	d		Methyl propanoate AND methanal ✓	1																					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
	e		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = (+)666(K) award 3 marks $\Delta S_{\text{sys}} = (+) 154.7 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$ $T = \Delta H/\Delta S_{\text{sys}}$ OR $T = 103000/154.7 \checkmark$ $T = (+)666 \text{ (K)} \checkmark$	3									
	f		<table border="1"><tr><td>Change</td><td>Increase d temper ature</td><td>Increase d pressure</td><td>Use of a catalyst</td></tr><tr><td>Effect on K_c</td><td>Increase</td><td>No change</td><td>No change</td></tr></table> $\checkmark \checkmark$	Change	Increase d temper ature	Increase d pressure	Use of a catalyst	Effect on K_c	Increase	No change	No change	2	All 3 correct 2 2 correct 1
Change	Increase d temper ature	Increase d pressure	Use of a catalyst										
Effect on K_c	Increase	No change	No change										
	g		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 4390(dm ³) award 3 marks Unit conversion, $n = 25000/142$, $p = 150000$, $\checkmark$ Use of $pV = nRT$ and 50% yield, $V = 0.5 \times 25000 \times 8.314 \times 900/142 \times 150000 \checkmark$ Evaluation and conversion to dm ³ 4390 $\checkmark$	3	ALLOW 2 or more sf								
	h		Allows reaction to occur at lower temp AND less energy used $\checkmark$	1									
			Total	17									

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
26	a	i	 Correct arrangement of flask and thermometer ✓ Correct arrangement of condenser, water in at bottom, condenser not 'sealed' ✓ More volatile liquid can be collected at its boiling point ✓	3	labels not essential apart from water connection anti-bumping granules not essential
		ii		1	ALLOW 'NH ₃ Cl' ALLOW any correct equation
		iii	Add alkali/ NaOH ✓ Put in separating funnel and collect organic layer ✓	2	
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 18.7(kg) award 3 marks Moles Mefenamic acid required = 15000/241 (= 62.24) ✓ Moles 2-chlorobenzoic acid needed = ans to 1 st point × 100/52 (=119.69) ✓ Mass 2-chlorobenzoic acid needed = ans to 2 nd point × 156.5/1000 = 18.7 (kg) ✓	3	ALLOW ecf throughout ALLOW 2 or more sf

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	c	<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes the appearance of the infrared and mass spectra in detail. AND Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes the appearance of the infrared. OR Describes the appearance of the mass spectra in detail. AND Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Describes the appearance of the infrared. OR Describes the appearance of the mass spectra. OR Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the</i>	6	Indicative scientific points may include: Absorbances on Infrared: • About 3300-3500 N-H amines • 2500-3300 O-H carboxylic acid • 1700-1725 C=O carboxylic acid • 1450-1650 several peaks Arenes • 3000-3100 C-H arenes • About 2850-2950 C-H alkyl groups Mass spectrum peaks • Molecular ion peak at 241 (allow ecf from (c)) • suggestion of a fragment (eg 196 – COOH missing) Identification of structure: • Fingerprint region unique to compound • Compare with database to confirm identity • Molecular ion gives relative molecular mass which matches that of mefenamic acid. • Fragments consistent with functional groups present

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>evidence may not be clear.</i> 0 marks No response or no response worthy of credit		
			Total	15	
27			B	1	
			Total	1	
28			B	1	
			Total	1	

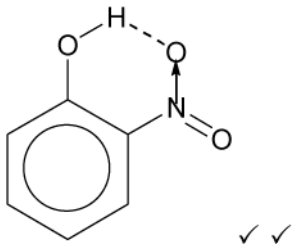
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a		Orange colour goes green ✓ Primary alcohols reduce / react/are oxidised by dichromate; tertiary do / are not ✓	2	Look for a comparison. ALLOW recognition of description of primary / secondary alcohol based on H attached to C and etc.. Examiner's Comments This question was well answered.
	b		Technique used <u>distillation</u> ✓ Homologous series of product <u>aldehyde</u> ✓ Technique used <u>reflux</u> ✓ Homologous series of product <u>carboxylic acid</u> ✓	4	DO NOT ALLOW condensation DO NOT ALLOW structures for homologous series e.g. C=O or COOH DO NOT ALLOW oxidation Examiner's Comments This question was well answered.
	c		134 ✓	1	Examiner's Comments This question was straightforward but required care when converting from the skeletal to molecular in order to work out the m/z value.
			Total	7	

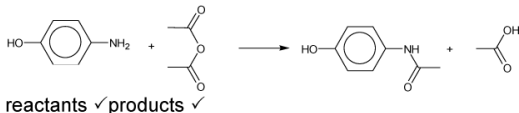
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30	a	i	$2\text{CH}_3\text{COOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{CH}_3\text{COONa} + \text{CO}_2 + \text{H}_2\text{O}$ formulae ✓ balancing of correct formulae ✓	2	ALLOW any unambiguous formulae (including molecular formulae) ALLOW H_2CO_3 as a product in a balanced equation for 1 mark IGNORE state symbols Examiner's Comment: (i) Most candidates were able to score both marks here, when only 1 mark was awarded this was usually for identifying H_2CO_3 incorrectly as a product of the reaction.
		ii	FIRST CHECK ANSWER LINE If answer = 11.25 or 11.3 (cm^3) award 2 marks amount $\text{CH}_3\text{COOH} = 25 \times 0.450/1000$ OR 0.01125(mol) ✓ volume $\text{Na}_2\text{CO}_3 (= 0.5 \times 0.01125 \times 1000/0.500) = 11.25 (\text{cm}^3)$ ✓	2	ALLOW ecf from 1:1 ratio in a(i) ALLOW 3 or more sf Examiner's Comment: In this calculation candidates used the appropriate equation to determine the number of moles of ethanoic acid, and then to determine the volume of sodium carbonate required (11.25cm^3). Where candidates had not given the correct equation in a(i) credit was allowed for correctly calculating a volume based upon their answer, usually calculating a value of 22.5cm^3 from an equation with a 1:1 ratio of reactants.
	b		$\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$	1	IGNORE state symbols ALLOW arrow for equilibrium sign Examiner's Comment: Most candidates scored this mark successfully.
			Total	5	

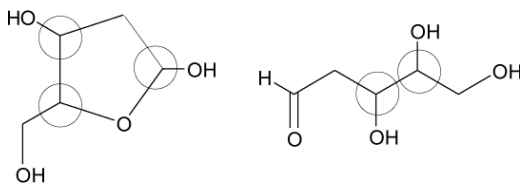
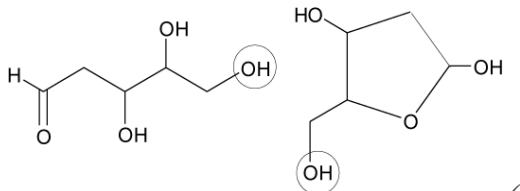
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31		i	FIRST CHECK ANSWER LINE If answer = 13.5 / 14(g) award 2 marks amount 4- nitrophenol = 5.0/139 OR 0.03597 (mol) AND mass phenol to give 100% = 5.0 × 94/139 OR 3.381 (g) ✓ scaling by 100/25 to get 13.5 / 14 (g) ✓	2	ALLOW ecf Any number scaled by 100/25 and to 2 or 3 sf scores second mark (if first mark not scored) Examiner's Comment: Where candidates failed to score here was in not correctly scaling up their calculated mass of phenol from 3.38g to 13.5g or 14g(2sf).
		ii		2	ALLOW on NO₂ group: • double bond to either oxygen with a single or dative bond to the other • one and a half' bonds to each oxygen One mark for correct bonding within NO₂ group One mark for hydrogen bond between correct H and O (even if bonding wrong) Examiner's Comment: Many candidates struggled with this question, suggesting that they are unfamiliar with the bonding within the NO₂ group, but, in many cases they did correctly identify where the internal hydrogen bond would form and so scored 1 mark.
		iii	reduction AND amine	1	Examiner's Comment: This question was not very well answered, very few candidates recognised that the conversion from a NO₂ functional group into a NH₂ functional group is an example of a reduction reaction and so failed to score this mark.

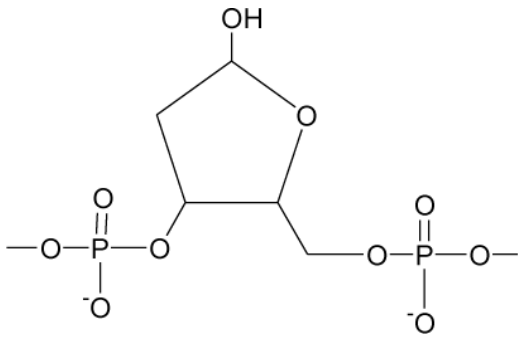
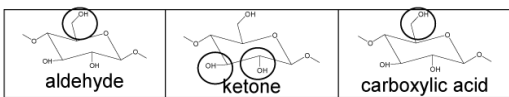
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	 reactants ✓ products ✓	2	IGNORE non-skeletal formulae / ambiguous attachments Allow correct use of Ethanoyl chloride for 1 mark Examiner's Comment: This question was generally well answered. Most candidates drew appropriate skeletal structures for the reactants, and it was pleasing to see so many correct representations for the anhydride, and subsequently identifying the products of the reaction.
		v	dissolve in minimum volume of <u>hot</u> water / solvent ✓ filter (hot solution) removing insoluble impurities ✓ allow to crystallise / AW ✓ filter, soluble impurities removed / remain in solution ✓	4	ALLOW wash (and dry) crystals - soluble impurities are washed away ✓ Examiner's Comment: There were very few blank responses to this question. Candidates often identified the steps involved in the process and could communicate this effectively. Weaker candidates often lost marks for not correctly identifying where insoluble impurities were removed, or for failing to identify the removal of soluble impurities at the end of the process. The quality of response may be linked to the use of this task within the set of expected practical's that candidates are expected to undertake as they move through the course.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
32	a	i		1	All 5 Carbon atoms must be circled Examiner's Comment: The most common error here involved candidates failing to identify that the carbon atom bonded to the OH group of the pentose ring was also a chiral centre and so did not score this mark.										
		ii	aldehyde ✓	1	NOT carbonyl here Examiner's Comment: Most candidates scored this mark with the only common error was identification of the functional group as a carboxylic acid rather than an aldehyde.										
		iii	<table border="1"><tr><td colspan="2"><i>one form</i></td></tr><tr><td>test 1 mark ✓</td><td>result linked to appropriate test 1 mark ✓</td></tr><tr><td>heat with Fehling's / Benedicts solution</td><td>(brick) red ppt</td></tr><tr><td>add Tollens' reagent and warm</td><td>silver mirror / AW</td></tr><tr><td>heat with acid dichromate</td><td>goes green</td></tr></table>	<i>one form</i>		test 1 mark ✓	result linked to appropriate test 1 mark ✓	heat with Fehling's / Benedicts solution	(brick) red ppt	add Tollens' reagent and warm	silver mirror / AW	heat with acid dichromate	goes green	2	Reagents may be specified (eg 'silver nitrate and ammonia' for Tollens') Examiner's Comment: Many candidates scored at least 1 mark, with the most common error being to incorrectly identify the reaction conditions associated with the tests, however where the test was identified the correct result was given and scored the appropriate mark.
<i>one form</i>															
test 1 mark ✓	result linked to appropriate test 1 mark ✓														
heat with Fehling's / Benedicts solution	(brick) red ppt														
add Tollens' reagent and warm	silver mirror / AW														
heat with acid dichromate	goes green														
		iv	 OH / it is attached to a C with 2H / one C-C bond / attached to a carbon that is only bonded to one other carbon / R group ✓	2	Both OH groups must be circled Examiner's Comment: Well answered. Candidates correctly identified the correct OH groups and explained why these groups were primary alcohol groups.										
		v	Water / a small molecule is not produced / both have same molecular formula	1	Examiner's Comment: Again, a well answered question. The vast majority of candidates recognised that water / a small molecule was not a product of the reaction.										
		vi	$\text{-CHO} + \text{HO-} \rightarrow \text{-CH(OH)-O-}$	1	ALLOW any unambiguous representation Examiner's Comment: Very few candidates scored this mark, and many left the space for the answer blank.										

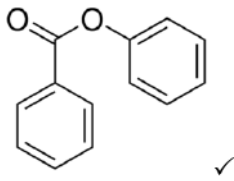
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		 correct bonding in phosphates ✓ correct connection of phosphates AND correct ring structure ✓	2	Examiner's Comment: This question was attempted by the majority of candidates, however, very few candidates scored more than one mark, with a significant number scoring 0. The most common error was the failure of candidates to realise that when the phosphate groups bond to the deoxyribose ring that all of the hydrogen atoms are lost in the formation of water, and therefore when candidates left OH groups attached to the central phosphorous atom this cost them one mark. However, it was pleasing to note that they did know where the phosphate groups bonded to the ring and so the second mark for showing the correct connection of the phosphate groups to the pentose ring was often awarded.
			Total	10	
33			 aldehyde ketone carboxylic acid	3	ALLOW just CH circled or C as well (as shown) Both circles must be shown for the ketones. If only carbon atoms have been identified, mark incorrect once and apply ecf Examiner's Comment: This question was generally well answered with most candidates scoring at least two marks for correctly identifying the OH groups that could be converted into an aldehyde or carboxylic acid. They often failed to score the third mark as they only identified one of the secondary OH groups in the middle diagram.
			Total	3	
34			B	1	<u>Examiner's Comments</u> This relates to a practical preparation that the candidates will likely have done, but C and D were very frequently seen.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35			A	1	Examiner's Comments More than half the candidates scored this mark. Option B, the tertiary alcohol, was the most frequently seen incorrect answer.
			Total	1	
36			A	1	Examiner's Comments Visualising the different ways this molecule could have water eliminated proved difficult for candidates. It was designed to be a high demand question.
			Total	1	
37			CO₂ is used in 36.2 so it removes a greenhouse gas from the atmosphere, (this is greener) ✓ Plus 2 from: ✓✓ - Both reactions need high T as both are endothermic but become more feasible at higher T as both have + ΔS, so no difference - Both reactions give a higher yield at lower T - Both need low pressure as 2 moles → 4, so no difference 36.2 produces less hydrogen per mole of methane, so less green/ Atom economy is lower in 36.2. (ORA)	3	ALLOW 36.2 requires more energy than 36.1, so less green Comments about 36.2 producing more toxic CO must be qualified (burn off → CO₂ or use as fuel) to score. Toxicity alone does not score. Examiner's Comments There were some very good answers, but others were vague and concentrated on the wrong things. Many identified the advantage of using CO₂ as a raw material but did not say why or used vague terms such as 'pollutant'. A lot focused on the CO produced, rather than the moles of hydrogen produced or atom economy.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38	a	i		1	ALLOW formulae of benzene rings using circle (and showing hydrogens) the key for the mark is the ester bonding correct. Benzene structure is needed NOT cycloalkane NOT C₆H₅ <u>Examiner's Comments</u> This calculation could be approached either by using 'reacting masses' or moles and both methods were used in about equal measure. Some errors in the calculation of formula mass crept in but with error carried forwards still gained marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 39.65/40(%) award 3 marks Reacting mass ratio = 94 : 198 ✓ Theoretical mass of phenyl benzoate formed = $\frac{198}{94} \times 4.91$ = 10.34 ✓ % yield = $\frac{4.10}{10.34} \times 100 = 39.65/40(\%)$ ✓	3	ALLOW range of answers allowing for early rounding 39.65 – 41.41% ALLOW Moles phenol = $4.91/94 = 0.05223$ ✓ Moles phenyl benzoate = $4.1/198 = 0.0207$ ✓ % yield = $0.0207/0.05223 \times 100 = 39.65$ ✓ If candidate has simply used the two calculated masses and has 83.5% (84%) allow one mark ✓ ALLOW ecfs from marking points 1 and 2 Examiner's Comments The response of many candidates did not describe the basic practical steps needed to get the sample into a suitable tube for determining the melting point of the solid (as described in the course text book). The most commonly scored marking point was for the identification of the range over which the solid melted. Exemplar 3 Melting point determination, Seal one end of a glass capillary and dip the solid granules to the bottom. Gently heat the capillary in a suitable liquid, remove when solid begins to melt and when it stops. Record temperature. [3] This response succinctly describes the practical procedure when melting point capillary tubes are used to determine melting point, including how to get the solid to the bottom of the tube.
	b	i	$C_6H_5COCl + H_2O \rightarrow C_6H_5COOH + HCl$ ✓	1	ALLOW correct structural formulae or correct mixtures of formulae
		ii	Test used to see whether any (unreacted) phenol (left), (would go purple if some remained) ✓	1	Both ideas needed

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Seal/melt end of melting point/capillary tube (in Bunsen) ✓ Tap/tip/pack a small amount of solid to bottom of tube ✓ Put tube in mp apparatus, allow temperature to rise <u>slowly</u> until solid melts OR record when it first starts to melt and when it finishes ✓	3	If unusual methods used please contact team leaders e.g. Siwoloboff's method, melting point bench
		iv	Indicates the presence of impurities / purity ✓	1	ALLOW simply- indicates purity of product
		v	Solute must have high solubility(in solvent) when hot, but low when cold/ AW ✓	1	DO NOT allow doesn't react with the product

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		if more than one spot shows up on tlc ✓ phenyl benzoate impure ✓ ORA for mp 1 and 2 however cannot assess overall purity/cannot tell how pure or impure it is ✓ not quantitative / is qualitative ✓	4	Diagrams can be used here ALLOW 'quantity' or references to % by mass of product Examiner's Comments  Misconception A significant number of candidates did not understand that R_f values did not address the requirement for describing what you would expect to see on a thin layer chromatography of the product mixture. To address the description statement examiners were expecting to see comments on spotting patterns, for either a pure or impure product, on the chromatogram. Exemplar 4 The student is correct, but this will only provide a ~~quantitative~~ ^{qualitative} analysis, not a quantitative one. If the sample is impure, then the phenyl benzoate spot would split into various different spots, with these other spots having R_f values equal to that of phenol or benzoyl chloride. If these spots appear, then the sample is impure and if they don't then the sample is pure. However, these spots will appear no matter the concentrations of the impurities in the sample, so you wouldn't be able to obtain a percentage purity value from thin-layer chromatography. A titration would be needed to get that. A strong answer; the expected observations asked for in the stem of the question have been addressed as well as the broad idea of the method giving only a qualitative measure of the level of purity/impurity.
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
39		i	$C_2H_3^+$ ✓ $C^{13}C_2H_6^+$ ✓	2	ALLOW structure, eg $CH_2=CH^+$ or CH_2CH^+ or CH_3C^+ ALLOW other unambiguous representations Award one mark for both correct species without plus sign ALLOW formula with comment that ONE of the C atoms is a ^{13}C isotope for MP2 Examiner's Comments Many candidates lost marks here for failing to include the charge on the species identified. However, if they had correctly identified the species and this was their only error then 1 mark was credited. The other common error was failing to recognise that the peak at 43 was a result of the presence of one atom of the Carbon-13 isotope in the fragment. Many candidates gave a formula of $C_3H_7^+$ even though they are told the molecular formula for propene in the stem of the question.
		ii	Both have same type and number of atoms / same molecular formula ✓ Sum of accurate atomic masses would be the same (AW) / same M_r ✓	2	Examiner's Comments This question ought to have been straightforward. However many candidates gave incomplete responses. They either correctly stated that the structural isomers had the same formula mass, or that they had the same molecular formula. However, many candidates, having identified one of these two key statements, then left that as their final answer. With two marks being available candidates should have realised that they needed to make two statements.
		iii	Any two from: IR : propene would have alkene $C=C$ ✓ at 1620-1680 ✓ OR alkene $C-H$ ✓ at 3000 – 3100 ✓ CNMR: propene would have 3 peaks ✓	4	IF only one method chosen, a maximum of two marks can be awarded. No marks available for identification of methods that can be used, all marks are for the reasons provided. ALLOW environments for peaks for both types of NMR

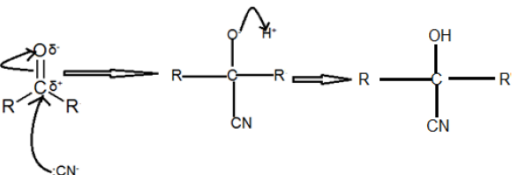
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			cyclopropane would have 1✓ OR propene would have (two) peak(s) at 110-160 ✓ C=C ✓ HNMR: propene would have 3 peaks ✓, cyclopropane would have 1 ✓ OR propene would have (two) peak(s) at 4.5 – 6 ✓ H-C=C ✓		ALLOW propene has multiplet ✓ from central CH ✓ <u>Examiner's Comments</u> There were a few issues raised in this question, which teachers may wish to consider when teaching this topic. This question was characterised by incomplete responses, or responses that lacked precision. To score well on this question, candidates needed to demonstrate their understanding of spectroscopic techniques precisely. This question was of high demand and this was reflected in the marks credited. Very few candidates scored full marks, and many candidates struggled to score more than two marks. Many chose appropriate methods to use, but then struggled to explain how the method chosen would distinguish between the two isomers. Many responses identified that one of the isomers contained a double bond, which was absent in the other isomer, but did not say how the method chosen would identify which isomer contained the double bond. Alternatively, if they did identify that propene had a double bond present, it was not linked to the specific data values quoted for IR spectroscopy, CNMR or HNMR spectroscopy. Also candidates knew that the splitting patterns in CNMR and HNMR were dependant on the environments of the carbon (or hydrogen) atoms and that the pattern could be used to identify the isomer, but again did not show precision in their responses.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
40	a		$ \begin{array}{ccccc} & \text{H} & \text{H} & \text{H} & \\ & & & & \\ \text{H} & - \text{C} & - \text{C} & - \text{C} & - \text{H} \\ & & & & \\ & \text{H} & \text{O} & \text{H} & \\ & & & & \\ & & \text{H} & & \end{array} $ ✓ ¹³C spectrum has only 2 peaks so only 2 carbon environments ✓	2	ALLOW OH <u>Examiner's Comments</u> In this question there were some very good responses, but others lost marks through not thinking things through or not reading the question closely enough. Many got 2 carbon environments and then gave the structure as ethanol, forgetting that it had come from propene. Others gave propan-1-ol, neglecting the fact that there were only 2 carbon environments. A number omitted the H atom on the central C which shows the importance of checking drawn structures. Almost all the answers gave full structural formulae.
	b		Acidified potassium/sodium dichromate AND heat/high temperature ✓	1	IGNORE reflux or distil IGNORE dichromate or Cr₂O₇²⁻ alone <u>Examiner's Comments</u> In this question we wanted the reagents, so dichromate(VI) alone was insufficient. Sometimes the incorrect oxidation state was given. We wanted to see heat for the conditions and ignored reflux or distil as these would depend on which alcohol had been given in the previous part. A significant number of candidates lost the mark as a consequence of this. The number of candidates getting completely incorrect reagents were few.

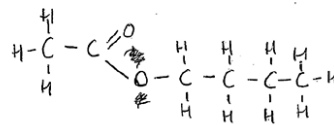
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
C	 Dipole ✓, both curly arrows ✓ intermediate and curly arrow and product ✓ Nucleophilic addition ✓	4	Curly arrow on carbonyl must start at double bond and end on oxygen atom. Other curly arrows must start either at lone pair or negative charge and point either to atom attacked or bond between atoms. ALLOW dipole and movement of electrons to O for 1 mark , then C⁺ intermediate and attack by CN⁻ for the second mark Intermediate and final product must have correct bonds (i.e. not through the N atom) <u>Examiner's Comments</u> It was clear that many candidates had revised this mechanism and gave very clear equations for it. Others did not include the dipoles, had arrows starting and finishing in vague places, had the initial attack by the nitrogen atom and a partial charge on the intermediate.

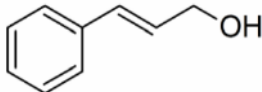
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	d	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Deduces correct structure with detailed evidence referring to all three spectra. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Deduces correct structure using some evidence. OR Deduces compound A is an ester with evidence from at least two spectra. OR Gives detailed analysis of three spectra while failing to determine the structure of compound A. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Gives some evidence from two spectra. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	6	Indicative scientific points may include: Infrared spectrum: C=O as strong absorbance at approx 1750 cm^{-1} No O–H from carboxylic acid or alcohol C–H at approx. 2950 cm^{-1} possibly ester NMR: 5 proton environments as 5 peaks $\delta = 0.9, 1.1, 1.6$ H–CR. $\delta = 2.3$ HC–C=O $\delta = 4.0$ HC–O Splitting: 0.9, 1.1 and 4.0 triplets so 2 protons attached to adjacent C/ $\text{CH}_3\text{--CH}_2$ 2.3 quartet so 3 protons attached to adjacent C/ $\text{CH}_2\text{--CH}_3$ 1.6 multiplet, several protons attached to adjacent C, possibly $\text{CH}_3\text{CH}_2\text{CH}_2$ Mass Spectrum: Mol mass is 116 Extra detail Sensible discussion of at least 1 fragment e.g. peak at 87 loss of CH_3CH_2 or peak at 73 loss of $\text{CH}_3\text{CH}_2\text{CH}_2$ or peak at 57 due to $\text{CH}_3\text{CH}_2\text{C=O}^+$ OR $116 - 6\text{C} = 44$ (2O) possibly ester Structure is Examiner's Comments A significant number of candidates gave a Level 3 answer and an impressive number had the structure completely correct. An even greater number knew it was an ester. Of the lower scoring candidates, the C–H absorbance was wrongly attributed to O–H, and there were also suggestions of arenes not borne out by the spectroscopic data or the fact that it can be made from propene.

Mark Scheme

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					Exemplar 8 The IR shows no O-H peak due to the lack of a broad peak at 3000 but a less broad peak shows C-H from alkanes are present. The peak 1700 shows a C=O is present and at 1750 shows an ester C=O is present. The ¹H NMR peak at 4.0 ppm shows there is 2 H on the carbon to the H-C=O of the ester. The multiplet H-C-R suggests a methyl CH₃ at the end of chain and the along side with the different shift shows the different hydrogen environments. The Quartet peak at 2.3 ppm shows 3 hydrogens on the carbon adjacent to the CH=O making it a methyl alkyl ester group. The Mass spec gives the Mr of 116 which when 6 carbons are known each have 12 Hydrogen and 2 oxygens present. Structure of compound A  [5] This candidate has correctly identified all the absorbances on the infra-red spectrum and did not confuse the C-H absorbance with O-H as some did. They have used the molecular ion peak on the mass spectrum with other data to get the molecular formula, although they have not considered the fragments. They have correctly identified the chemical shifts of protons next to the ester group and made an attempt at interpreting the splitting. They have deduced the structure is that of an ester, but they have not quite used the splitting pattern and the fact that it could be made from propene to get the correct ester. This response was therefore judged to be at Level 2, and credited 4 marks.
			Total	13	
41			B	1 AO 1.1	
			Total	1	

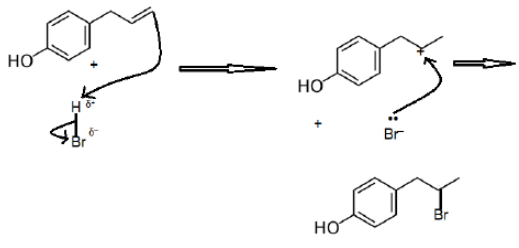
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance															
42	a		(neutral) iron(III) chloride/ FeCl_3 AND (orange to) purple (AW) ✓	1 AO 1.1	ALLOW iron(III) nitrate/ $\text{Fe}(\text{NO}_3)_3$ if starting colour is given it must be orange or brown, any other colour is CON <u>Examiner's Comments</u> Colour changes generally were not well known and there were a variety of incorrect starting colours given.															
	b	i	<table><tr><td></td><td>Reagent</td><td>Conditions</td><td>Colour change</td></tr><tr><td>Oxidation Alcohol</td><td>$\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$</td><td>Distil</td><td>Orange to green</td></tr><tr><td rowspan="2">Aldehyde or ketone</td><td>Tollen's/ Ammoniacal Ag^+</td><td>Warm Heat</td><td>(Appearance of) Silver mirror (AW)</td></tr><tr><td>OR Fehling's (A and B) / Benedict's OR $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$</td><td>Heat under reflux</td><td>Blue → brick red Orange → green</td></tr></table> ✓ ✓ ✓		Reagent	Conditions	Colour change	Oxidation Alcohol	$\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$	Distil	Orange to green	Aldehyde or ketone	Tollen's/ Ammoniacal Ag^+	Warm Heat	(Appearance of) Silver mirror (AW)	OR Fehling's (A and B) / Benedict's OR $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$	Heat under reflux	Blue → brick red Orange → green	3 AO 1.2 x 3	1 mark per column of table correct OR if no complete column can score 1 for a fully correct row ALLOW acidified (potassium or sodium) dichromate as reagent in either or both tests. If another specific dichromate is identified it must be soluble. Formula must be correct. In second row, if a silver salt is named it must be soluble. For Fehling's solution or Benedict's solution ALLOW orange <u>Examiner's Comments</u> More candidates scored 2 for this than any other mark because they had heating under reflux for the conditions when distillation is appropriate for an aldehyde. Forgetting to acidify the dichromate was another problem, as well as not including the starting colour for Fehling's solution if that was used.
	Reagent	Conditions	Colour change																	
Oxidation Alcohol	$\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$	Distil	Orange to green																	
Aldehyde or ketone	Tollen's/ Ammoniacal Ag^+	Warm Heat	(Appearance of) Silver mirror (AW)																	
	OR Fehling's (A and B) / Benedict's OR $\text{Cr}_2\text{O}_7^{2-}/\text{H}^+$	Heat under reflux	Blue → brick red Orange → green																	
		ii	 ✓	1 AO 1.1	<u>Examiner's Comments</u> This was a difficult question and relatively few candidates scored the mark. Some had forgotten that A and B were aromatic so drew chains with multiple double bonds, others had the $\text{C}=\text{C}$ in the incorrect place or too few carbons.															

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	H₂, Ni 'heat and pressure' (or specified sensible values) OR H₂, Pt, room temp ✓	1 AO 1.1	ALLOW Ni/Pt as reagent or conditions Any other reagent is a CON <u>Examiner's Comments</u> This was a question where knowledge of factual details of organic reactions was not always strong enough. Many candidates gave the nickel catalyst but omitted the reagent, hydrogen.
		ii	Use of ethanoyl chloride or ethanoic anhydride ✓ Rest of equation correct ✓ $\text{CH}_3\text{COCl} + \text{C}_6\text{H}_4(\text{CH}_2\text{CH=CH}_2)\text{OH} \rightarrow \text{CH}_3\text{COOC}_6\text{H}_4(\text{CH}_2\text{CH=CH}_2) + \text{HCl}$ ✓ OR $(\text{CH}_3\text{CO})_2\text{O} + \text{C}_6\text{H}_4(\text{CH}_2\text{CH=CH}_2)\text{OH} \rightarrow \text{CH}_3\text{COOC}_6\text{H}_4(\text{CH}_2\text{CH=CH}_2) + \text{CH}_3\text{COOH}$ ✓	2 AO 2.7 x 2	If ethanoic acid is used SCORE 0 ALLOW any unambiguous structures <u>Examiner's Comments</u> Most candidates had forgotten that ethanoyl chloride or ethanoic anhydride were the reagents needed to esterify a phenol. Many of those who did remember used generic acyl chlorides or forgot the HCl or ethanoic acid product.
	d	i	Reagents and conditions: steam AND phosphoric acid (adsorbed onto silica) High T and P OR Conc sulfuric acid followed by water ✓ Conditions: Al₂O₃/alumina catalyst, heat. OR Conc sulfuric acid, (heat under) reflux AND Product (on equation) H₂O ✓	1 1 AO 1.2 x 3	If conc sulfuric acid is used in first reaction the water MUST clearly be added later to score mp1 Other reagents in either box is CON IGNORE pressure Check equation for product. State symbol not required but if given must be (l) or (g). (s) is CON <u>Examiner's Comments</u> This was also a low scoring question due to lack of detailed knowledge of reaction conditions studied at the beginning of the course.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	The dehydration of the secondary alcohol could give the double bond either in the new position or the original position ✓ A mixture of products (AW) ✓	2 AO 3.2 x 2	IGNORE references to position of equilibrium. Clear implication that both isomers would form is required for mp2 <u>Examiner's Comments</u> This was intended to be a testing question. A significant number of candidates were able to suggest that the double bond might re-form in the original place but did not always make clear that a mixture of the two products would form.
e		i	 Both curly arrows and partial charges on HBr ✓ Intermediate and attack of Br⁻ ✓	2 AO 1.2 x 2	Curly arrows must start on the bond concerned (or the lone pair or minus sign of Br⁻). They must point to the atom concerned or the bond that is to be formed. ALLOW R- for rest of structure Lone pair is not required on Br⁻ but if not present curly arrow must start at minus sign. Product is not required but if it is shown it must be correct for mp2 A valid mechanism leading to the anti Markownikov product scores 1 <u>Examiner's Comments</u> Although many candidates scored at least 1 mark, it proved difficult for others. In some cases the arrows were in the wrong direction or unclearly drawn. Some answers had the + charge on the incorrect carbon in the intermediate leading to the wrong product or attacked with the Br^{δ-} first.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	H must add first (in either reaction) ✓ Product 1 cannot form as $H^{\delta+}$ as it is the only electrophile (ORA) ✓ Product 2 could form as Cl^- can react with the carbocation (once the $H^{\delta+}$ has reacted) ✓	3 AO 3.2 x 3	Mp1 for clear implication of electrophilic reaction involving HBr Mp2 for identifying $H^{\delta+}$ as the only electrophile OR by stating that Br^- AND H_2O (NOT OH^-) are nucleophiles / not electrophiles. (IGNORE Cl^-) IGNORE comments comparing reactivity or steric factors in halide ions for mp3 <u>Examiner's Comments</u> This was designed to be a stretching question and proved predictably difficult. This idea is studied in connection with establishing the mechanism of addition to alkenes (DFq), but with bromine and other anions and water. It was more difficult to apply the idea to addition of HBr. Many candidates could explain that product 2 could be formed by the reaction of Cl^- ions to the carbocation. Sometimes this included the irrelevant comparison of reactivity of chlorine and bromine. Candidates found it less easy to explain why product 1 could not form as it involved the addition of 2 nucleophiles (Br^- and H_2O).
			Total	17	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
43	a	i	vacuum filtration/filtration under reduced pressure/suction filtration ✓ AND Any two from: Moisten/damp(en) filter paper /wash paper with water✓ wash solid/paracetamol with water ✓ suck dry / sucks to remove water/solvent ✓ crude paracetamol/solid left (on filter paper/in funnel) ✓	3(AO 2.7)(AO 3.4 x2)	Allow the word “pull” rather than “suck” In flask is a CON <u>Examiner’s Comments</u> Many good responses contained a detailed explanation of the technique. Others were rather vague and suggested a weaker understanding e.g. ‘pressure in flask decreases allowing liquid to pass through funnel’ or ‘the pump provides high pressure to make sure the water ends up in the flask’.
		ii	much quicker/faster ✓	1(AO 3.2)	<u>Examiner’s Comments</u> Many candidates recognised that vacuum filtration was faster, however others were often too vague, answering in terms of efficiency. (e.g. the simple statement, seen many times, ‘technique is more efficient’ did not score this mark).
	b		<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5-6 marks) Majority of indicative scientific points used as evidence from each spectrum to identify the compound as paracetamol. <i>There is a well-developed line of reasoning which is clear and logically structured.</i> Level 2 (3-4 marks) Some evidence from each spectrum used to identify the compound as paracetamol. OR Detailed evidence from two of the spectra used to identify the compound as paracetamol. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1-2 marks) Detailed evidence from one of spectra to	3(AO 3.1 x 4)(AO 3.2 x 2)	Indicative scientific points include: Information from IR • absorption at ~ 1650 suggests C=O present (cannot be 4-aminophenol) • big absorption around ~3300+ suggests presence of phenolic OH and/or NH (cannot be ethanoic anhydride or ethanoic acid) Information from ¹Hnmr • 5 unique proton environments (so cannot be other structures which have 4, 2 and 1 proton environments) • number of protons in ratio 3;2;2;1;1 • representing CH₃ two sets of 2 H's on ring and a single OH and NH on paracetamol (can be shown on annotated structure) Information from ¹³Cnmr • 6 unique carbon environments • cannot therefore be reactants or ethanoic acid (too many carbon) ORA

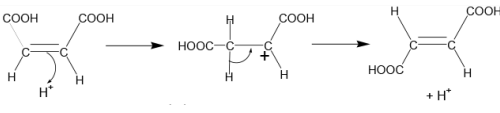
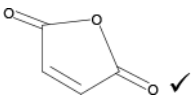
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			identify the compound as paracetamol. OR Some evidence used from two of spectra to identify the compound as paracetamol. OR Evidence from all spectra but compound not identified as paracetamol. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.		paracetamol • C=O; 4 groups of aromatic Cs Look for any evidence on the spectra i.e. annotations At Level 3 it would be expected that explanations of why it cannot be a specific substance would be included If paracetamol not identified (name or structure) can only score L1 <u>Examiner's Comments</u> A small, but significant, number of candidates did not read the question carefully enough and did not identify the compound at all, or produced a structure that was not one of the reactants or products. The best answers used all the spectra to not only to identify paracetamol as the compound, but also to explain why certain absorptions ruled out the other compounds featured in the synthesis.
			Total	10	
44			B	1 (AO2.7)	
			Total	1	
45			A	1 (AO1.1)	
			Total	1	
46			C	1 (AO1.2)	
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
47	<i>Please refer to the marking instructions on pages 4/5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Identifies A as phenol and B as propanone using the evidence from some tests, the mass spectrum for product A and the composition of product B. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Identifies A as a phenol and B as a ketone or C₃H₆O using the evidence from some tests OR the mass spectrum for product A OR the composition of product B. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Identifies A as a phenol OR B as a ketone using the evidence from some tests OR the mass spectrum for product A OR the composition of product B. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	6 (AO3.1 × 3) (AO3.2 × 3)	Indicative scientific points may include: Product A: • Is a phenol • It is weakly acidic, but not strong enough to react with sodium carbonate • Gives the purple colour with FeCl₃ • Mass spectrum shows that the M_r is 94 • Consistent with phenol, C₆H₅OH Product B: • Moles: C 5.175; H 10.3; O 1.735 • Empirical formula is C₃H₆O • Not an acid • Can be reduced to an alcohol so is aldehyde or ketone. • Does not get oxidised by Tollen's reagent so is a ketone. • propanone / CH₃COCH₃.
	Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
48	a	i	 one for each arrow ✓ ✓	2 (AO2.5 × 2)	One arrow must start) on the double bond and end pointing to H⁺ (or to the bond being formed) The other arrow must start and end on the bonds shown. Other arrows are CON
		ii	(Electrophilic) Elimination	1 (AO1.1)	
		iii	No, either of the Hs on the left C (of carbocation) could leave ✓ some ²H / D would be incorporated ✓	2 (AO3.2 × 2)	Examiner's Comments In this part, the mechanism in (e)(i) was found challenging by many candidates. Common errors included the inclusion of additional arrows in the first step and the arrow in the second step going to the carbocation rather than to the desired location to form the final double bond.
	b			1 (AO2.1)	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		<i>Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.</i> Level 3 (5 – 6 marks) Correct structure / identity deduced and detailed evidence related to the structure is provided from each spectrum. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Correct structure / identity deduced with detailed evidence from at least one spectrum. OR Structure / identity attempted with some correct evidence from a minimum of two spectra. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Correct structure / identity deduced with no relevant evidence. OR Structure / identity not given or incorrect, but some correct evidence from at least one spectrum. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or nothing of value	6 (AO3.1 × 4) (AO3.2 × 2)	Indicative scientific points may include: AO3.1 Analysis: IR: • C=O at 1700 • Broad OH 2500-3300 • COOH HNMR: • Three H environments • 1.2: Hs on C connected to C-H • 2.3: H on C connected to Cs with many Hs • 11.8 H in COOH CNMR: • Three C environments • two Cs in same environment • one C=O (at 183ish) • two C-C AO3.2 Evaluation: Compound A identified as 2-methylpropanoic acid Structure CH₃CH(CH₃)COOH presented in any unambiguous way
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
49	a	i	solvent for ester/(organic) product formed ✓	1 (AO2.3)	
		ii	Removes / neutralises acid (impurity) ✓	1 (AO1.2)	ALLOW reacts with acid
		iii	removes water / dries/dehydrates the mixture ✓	1 (AO1.2)	
		iv	(about) boiling point of ester / cyclohexane boils off before ester ✓	1 (AO2.7)	So methyl benzoate is the only product / substance collected.. ALLOW only pure product.
	b		FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 61(%) award 4 marks 8.0g of benzoic acid is $8.00/122 = 0.066\text{moles}$ ✓ 100% conversion gives $0.066 \times 136 = 8.976\text{g}$ ✓ % yield is $5.46/8.92 \times 100 = 61.2 / 60.8$ ✓ two sf = 61(%) ✓	4 (AO2.6 $\times 2$)(AO2.8 $\times 2$)	ecf on values actual values depend on when rounding done OR mol ester = $5.46/136 = 0.04$ OR % = $0.04 \times 100 / 0.066 = 60.6$
			Total	8	