

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

COLOUR BY DESIGN (CD)

SCORE

/407

PERCENTAGE

%

STEMUP

These questions belong to OCR, not to us.

The examination questions, mark schemes and examiner comments in this pack were written and published by OCR. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

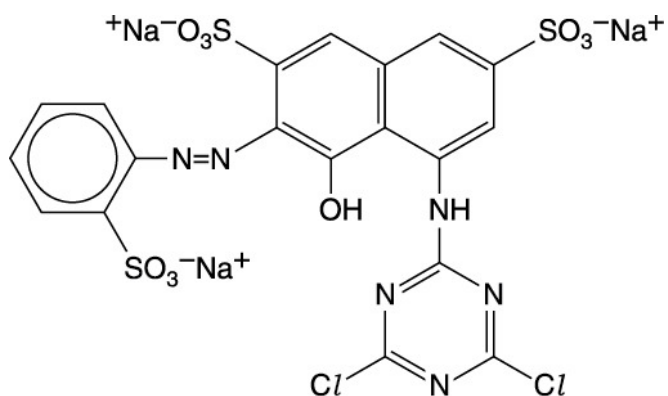
STEMUP is not affiliated with OCR and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. OCR has not endorsed, approved or been involved in the production of it. OCR and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

OCR publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at ocr.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

1(a) Procion Brilliant Red 2BS, shown below, is a 'fibre reactive' dye that attaches itself to wool by covalent bonds.



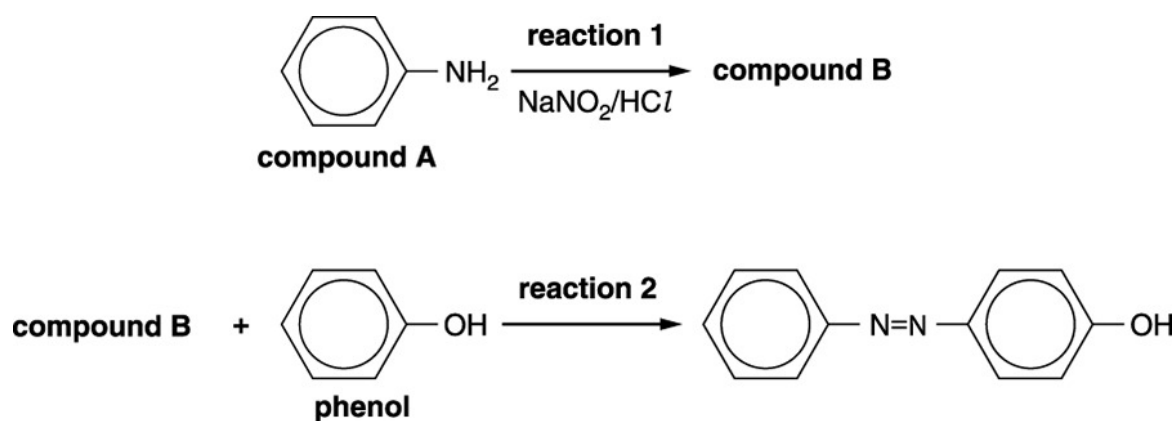
Procion Brilliant Red 2BS

Suggest the formula of **one** functional group on the dye that makes it more soluble in water.

Explain why your suggested group does this.

----- [2]

(b) 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]

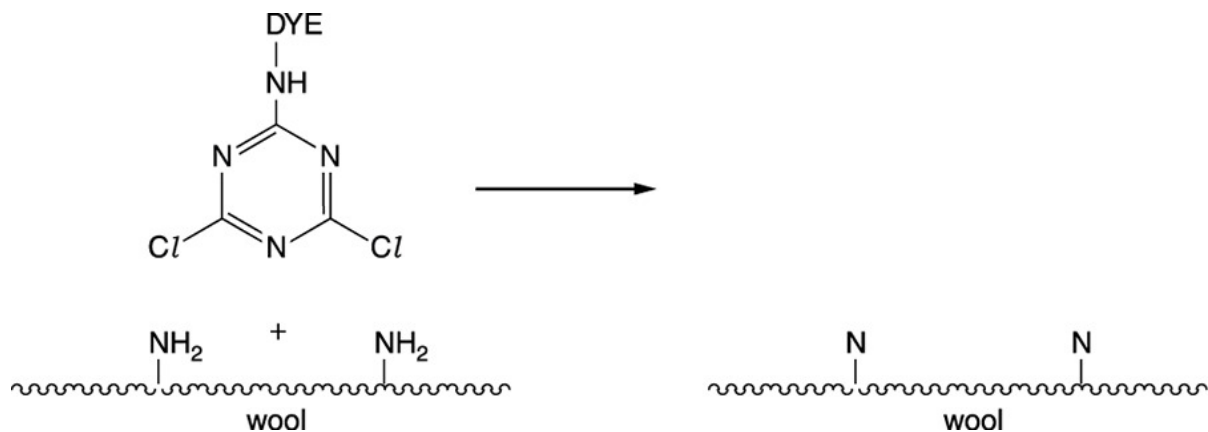
(iv) Phenol is acidic in solution. Carboxylic acids are also acidic but react in a way that phenols do not.

Give details of this acidic reaction of carboxylic acids.

-----[2]

(c) Procion Brilliant Red 2BS reacts with the side-groups in wool in a condensation reaction.

(i) Give **both** products of the reaction below.



[2]

(ii) It is often necessary to wash wool that has been dyed.

Give an advantage of a dye that is attached to wool by covalent bonds compared with a dye that is attached to wool by hydrogen bonds.

Explain why it has this advantage.

[3]

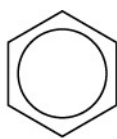
- (d) Explain, in terms of chromophores and electron energy levels, why different dyes have different colours.



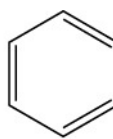
In your answer you should make it clear how your points link together.

[5]

- (e) C_6H_6 can be represented as either structure **C**, which is benzene, or structure **D**, which contains three separate double bonds.



structure C



structure D

- (i) Predict the reactions of structures **C** and **D** with bromine.

Give the **type** of reaction and the **skeletal formula** of the organic product you would expect in each case.

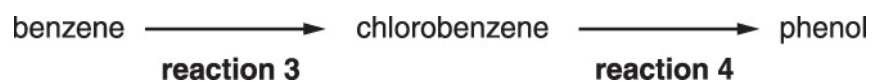
	Structure C	Structure D
Type of reaction		
Skeletal formula of organic product		

[4]

- (ii) What would structure **D** suggest about the bond lengths between carbon atoms in the ring? Explain your answer.

[2]

(f) Hydroxyl groups can be substituted on to aromatic rings by a reaction sequence, such as that shown below.



(i) Write an equation for reaction 3, giving the formula of a suitable catalyst over the reaction arrow.

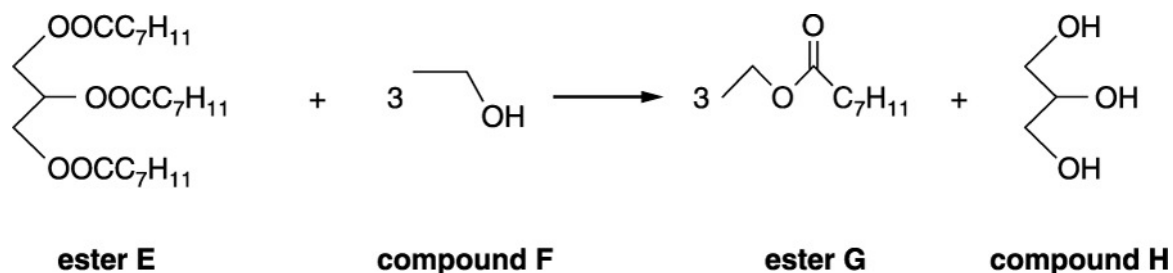
[2]

(ii) Suggest a reagent for reaction 4.

-----[1]

- 2 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.



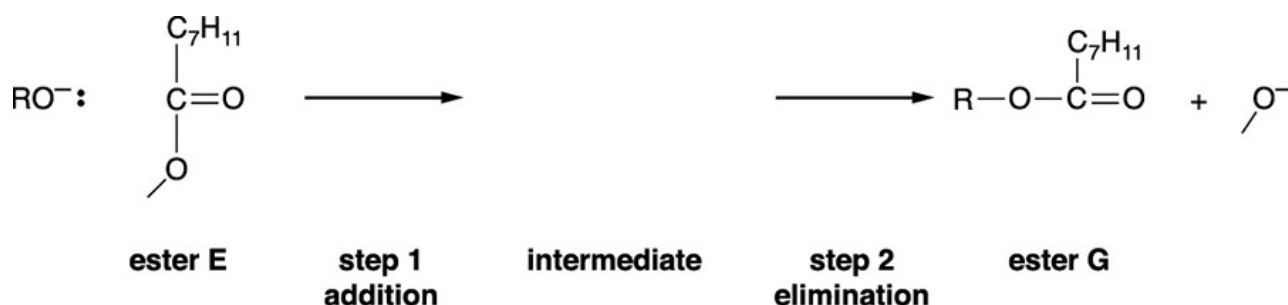
An alkaline catalyst is used in the process of trans-esterification.

The catalyst removes a proton from the alcohol, ROH, to form an RO⁻ ion.

The RO⁻ ion then attacks ester E.

The intermediate rearranges to eliminate one molecule of ester G.

- (i) Complete the mechanism for this reaction by adding the intermediate and the curly arrows showing the electron movements in **step 1** and **step 2**.



[3]

- (ii) What is the role of RO⁻ in the mechanism in **step 1**?

-----[1]

3(a) Benzene can either be represented as diagram A or diagram B below.

Explain, in terms of the reactions of benzene, why diagram A is often preferred.



diagram A

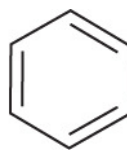


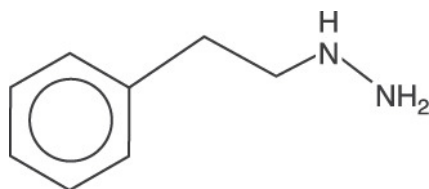
diagram B



In your answer you should make it clear how your points link together.

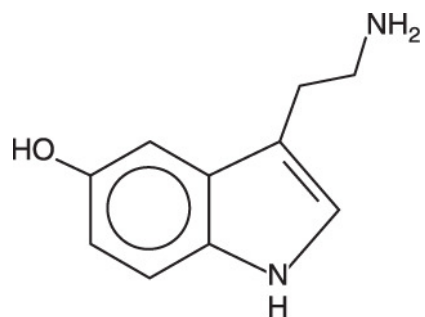
[4]

(b) Phenelzine is an antidepressant drug.



phenelzine

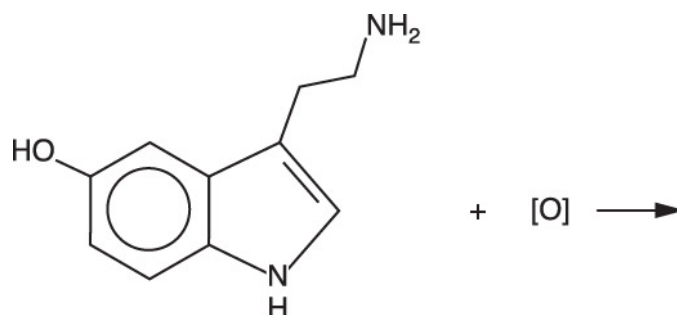
Phenelzine acts as an antidepressant because it irreversibly inhibits an enzyme. This enzyme catalyses the reaction of serotonin with an oxidising agent. Serotonin controls human mood.



serotonin

Complete **equation 2.1** below for the enzyme-catalysed reaction in which the $\text{-CH}_2\text{NH}_2$ group is oxidised to -CHO .

[O] represents an atom of oxygen supplied by the oxidising agent.



equation 2.1

[2]

(c) Another inhibitor of the enzyme is 'moclobemide'. This inhibits the enzyme **reversibly**.

- Name the substrate of the enzyme.
- Explain how moclobemide inhibits the enzyme action.
- Describe how increasing the concentration of the substrate would affect the rate of the reaction in **equation 2.1** when moclobemide is present.

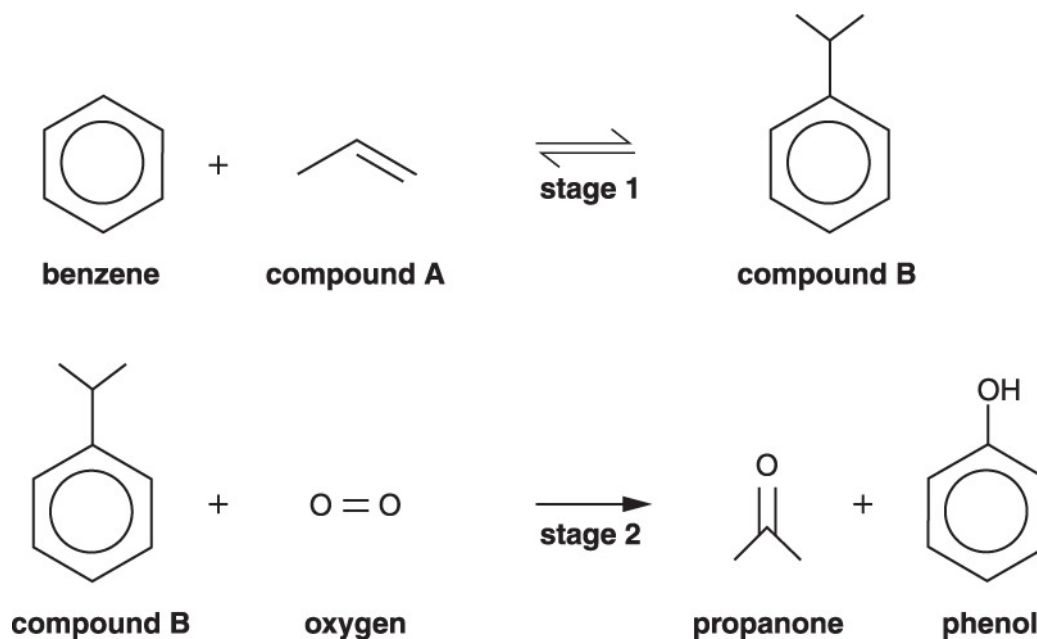
[4]

- Many aromatic compounds are coloured.

Explain, in terms of chromophores and energy levels, why these compounds are coloured whereas phenelzine is not.

[5]

4(a) Propanone and phenol are useful organic compounds. They are both manufactured from benzene by the two-stage process shown below.



(i) Name compound A.

-----[1]

(ii) The reaction in **stage 1** is described as a *Friedel-Crafts* reaction.

Give **one** similarity and **one** difference between this reaction and most other Friedel-Crafts reactions. Give your answer in terms of the **reactants** and **products**.

Similarity -----

Difference -----

[2]

(b) **Stage 1** is carried out at 250 °C and 30 atmospheres pressure in the gas phase. The reaction is exothermic.

- (i) Describe and explain the effect of increased pressure on the reaction in **stage 1**.

Answer in terms of the equilibrium yield and rate.



In your answer, you should relate your explanation to the equation for the reaction.

[4]

- (ii) Describe and explain the effect (if any) of increasing the temperature on the **equilibrium constant** for **stage 1**.

Suggest why a temperature lower than 250 °C is **not** used.

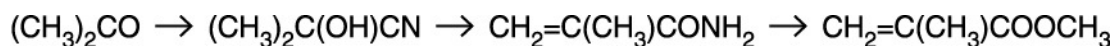
[2]

- (iii) What is the atom economy of the whole process (stages 1 and 2 taken together)?

Explain why this is beneficial to the environment.

[2]

- (c) Propanone is used to make 'methyl methacrylate' which is an important monomer for making 'acrylic' polymers. The process is outlined below.



propanone

compound C

compound D

methyl methacrylate

(i) Name compound **C** and give a reagent for its formation from propanone.

Name

Reagent

[2]

(ii) Name **two** functional groups in compound **D**.

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

(iii) Suggest a reagent that would react with compound **D** to give methyl methacrylate and ammonia.

..... [1]

(iv) Suggest, with a reason, the **type** of polymerisation that methyl methacrylate undergoes.

Give the **full** structural formula of the repeat unit of the polymer.

Type of polymerisation and reason

.....
.....

Repeat unit

[2]

(d) Phenol, C_6H_5OH , can be chlorinated. The resulting compounds are used to make antiseptic medicines.

(i) Name the mechanism of the reaction between phenol and chlorine.

-----[1]

(ii) Give the **molecular** formula of a monosubstituted chlorophenol (i.e. a molecule of phenol with one chlorine atom substituted for a hydrogen on the ring).

-----[1]

(iii) There are several monosubstituted chlorophenol isomers.

Give the total number of isomers.

-----[1]

(e) The compound IC/ reacts with phenol. One of the products is a monosubstituted phenol.

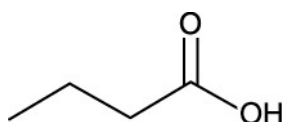
Suggest the structure of this product and suggest why this product is formed.

Structure

Reason

-----[3]

- 5(a) Butanoic acid (often called 'butyric acid') is a foul-smelling liquid that has been used by anti-whaling protesters to throw on board whaling ships.



butanoic acid

'Butyric' means 'buttery'. Butanoic acid is formed by hydrolysis when butter turns rancid (sour).

- (i) Butter consists mainly of triesters of propane-1,2,3-triol.

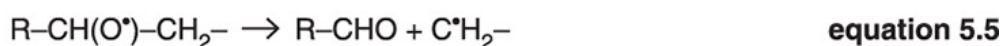
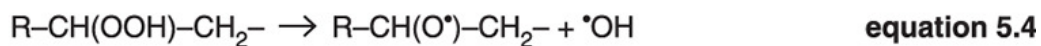
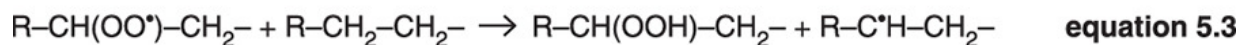
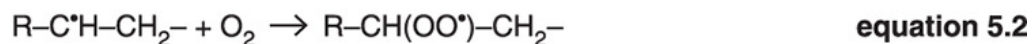
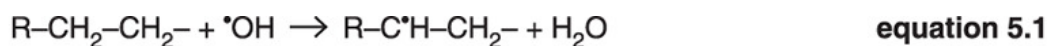
Draw the **full** structural formula of a triester molecule that hydrolyses to give three molecules of butanoic acid.

[2]

- (ii) Explain why this triester is an example of a *saturated* fat.

[1]

- (b) Fats also become rancid when they are oxidised. A mechanism for such a reaction is shown below. R represents an alkyl group.

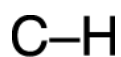


- (i) Use a 'dot-and-cross' diagram to explain why $\cdot\text{OH}$ is described as a *radical*.

-----[2]

- (ii) In **equation 5.1** a C-H bond is broken in a CH_2 group.

Complete the diagram to indicate the movement of electrons in this process.



[1]

- (iii) Name the **type** of bond breaking in (ii).

-----[1]

- (iv) Classify **equations 5.1 to 5.5** as initiation, propagation or termination by ticking the appropriate boxes in the table below.

Equation	Initiation	Propagation	Termination
5.1			
5.2			
5.3			

5.4			
5.5			

[2]

(v) The reactions in **equations 5.2 and 5.3** make a chain reaction.

Give the overall equation for this chain reaction.

[1]

(vi) The molecule R-CHO formed in **equation 5.5** is one of the rancid products produced by oxidation.

Name the functional group in this molecule.

This functional group has laboratory reactions that involve colour changes. Describe **one** of these reactions.

Name of functional group _____

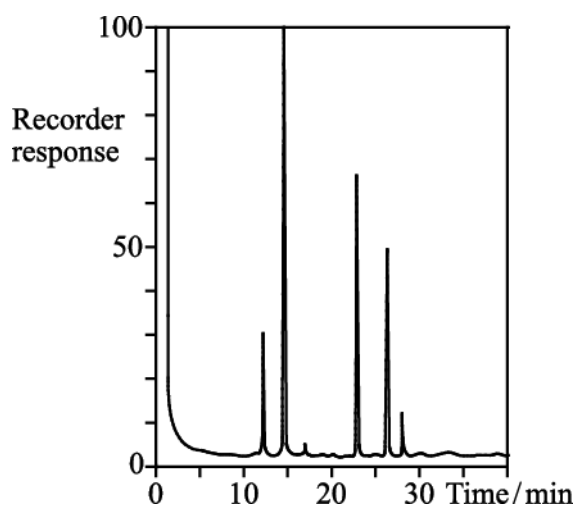
Reagent and conditions for reaction _____

Final colour _____

_____ [2]

- 6 Instrumental techniques are crucially important in the analysis of many mixtures. These may involve wide ranging areas such as in forensic work or the analysis of a potential forged painting.

The figure below shows a graphical analysis of a mixture using a particular technique.



Identify the technique used to produce this graph.

- A mass spectrometry
- B infrared spectroscopy
- C proton NMR spectroscopy
- D gas-liquid chromatography

Your answer

[1]

7 A pure sample of fat was known to be a triester of propane-1, 2, 3-triol with a fatty acid.

0.15 mol of the fat required 10.8 dm^3 of hydrogen at room temperature and pressure for complete hydrogenation.

Identify which fatty acid formed the triester.

A Palmitic acid, $\text{C}_{15}\text{H}_{31}\text{COOH}$

B Linoleic acid, $\text{C}_{17}\text{H}_{31}\text{COOH}$

C Oleic acid, $\text{C}_{17}\text{H}_{33}\text{COOH}$

D Stearic acid, $\text{C}_{17}\text{H}_{35}\text{COOH}$

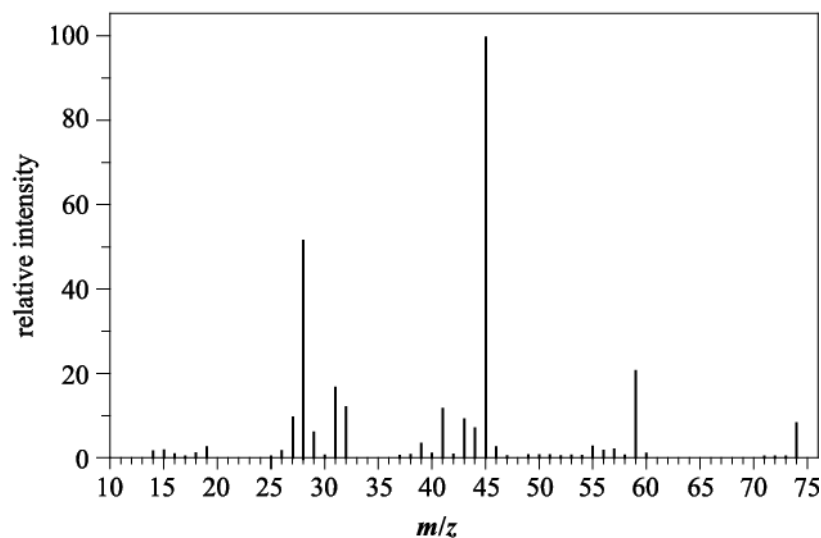
Your answer

[1]

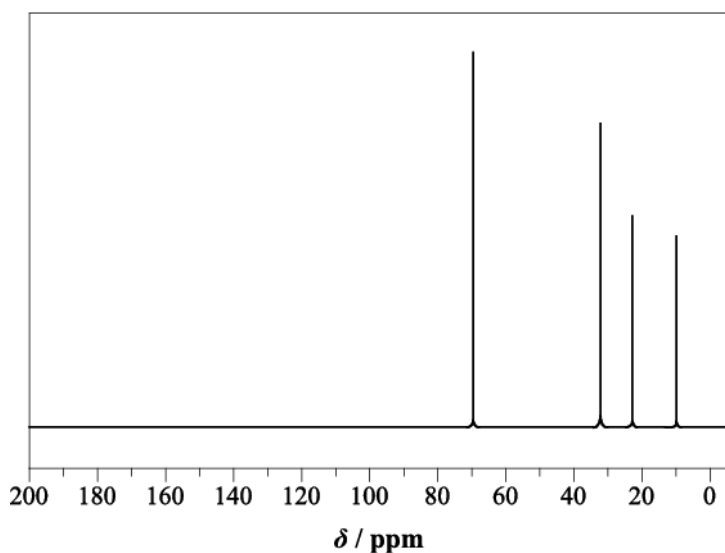
8 Ethanol is sometimes used as a biofuel to replace petrol in car engines. However it has several disadvantages.

* 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**.

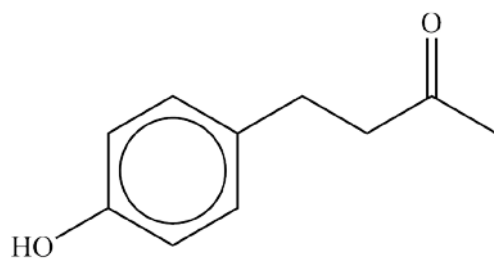
Compound **B** does **not** react with Tollens' reagent or NaOH .

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

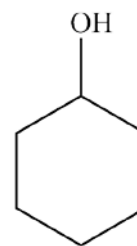
[illegible]

61

9(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.

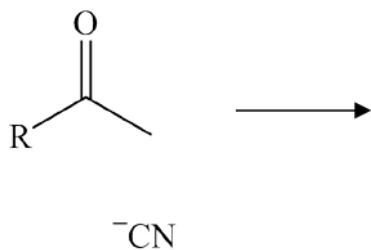
What technique could be used to show that two organic products are present in the mixture?

-----[1]

(c) Cyanide ions will react with raspberry ketone.

Complete the diagram below to show the mechanism for the formation of a cyanhydrin, showing the intermediate and the product.

Include curly arrows and partial charges where appropriate.



[4]

10 CH_3COCl reacts with benzene in a Friedel-Crafts reaction.

What is **not** correct about this reaction?

- A The reaction occurs without a catalyst.
- B A ketone is formed.
- C HCl is formed.
- D The reaction is electrophilic substitution.

Your answer

[1]

11 Which of the following will react with benzene?

1: NO_2^+

2: OH^-

3: NH_3

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer

☐

[1]

12 Which of the following will react with aldehydes?

1: cyanide ions

2: acid dichromate(VI)

3: Fehlings solution

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer

☐

[1]

13 Which of the following is / are correct?

	Reaction	Description
1	bromination of benzene	electrophilic substitution
2	bromination of alkenes	electrophilic addition
3	bromination of alkanes	nucleophilic substitution

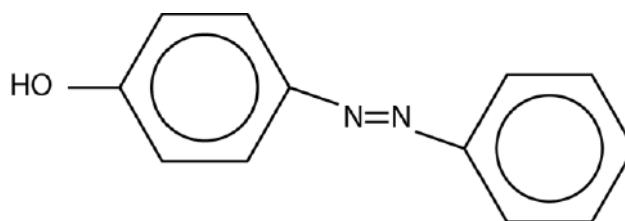
- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

[1]

14 Synthetic dyes can be made from other components of coal tar that have benzene rings.

One such dye is the yellow dye shown below.



yellow dye

(i) In a benzene ring, all the C-C bond lengths are equal.

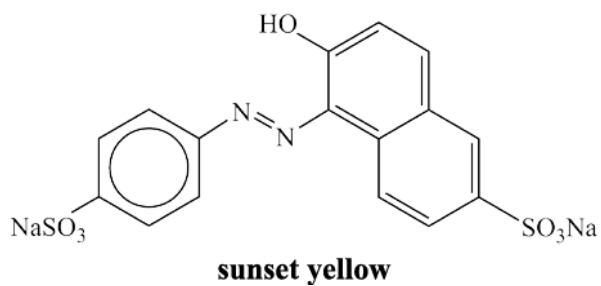
Describe how the bonding in benzene accounts for this.

[2]

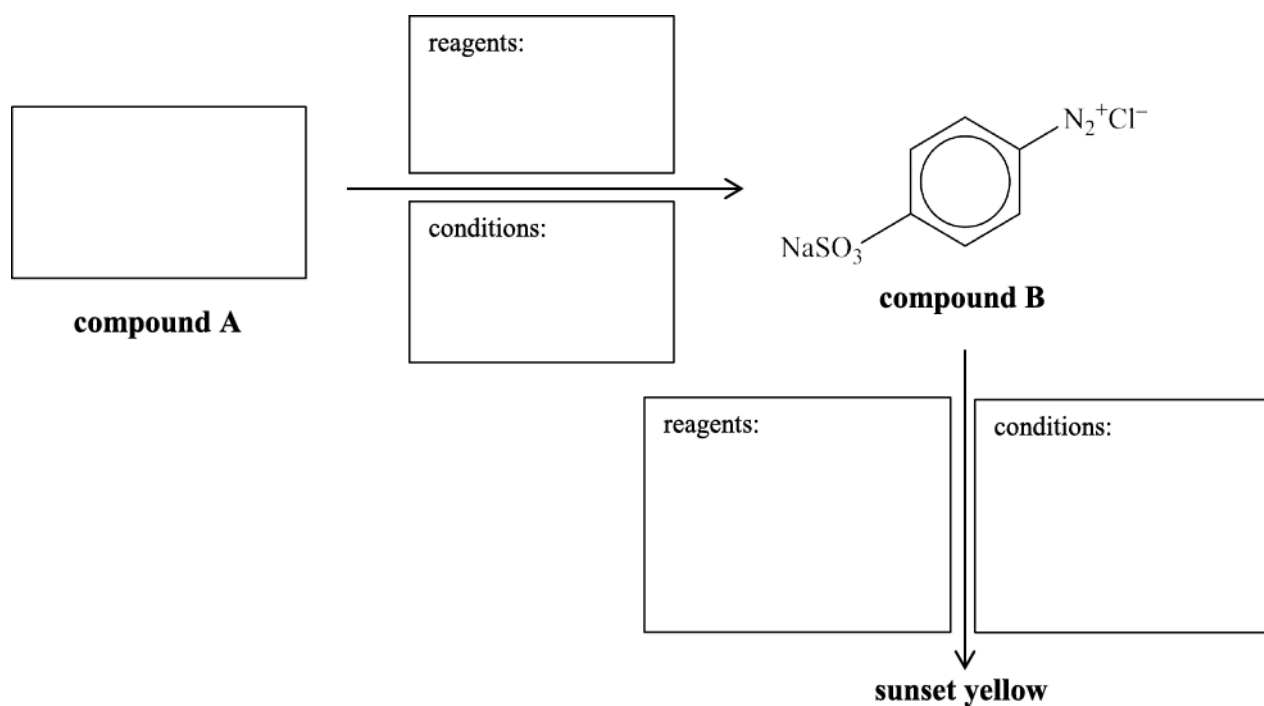
(ii) Explain, in terms of delocalisation and energy levels, why the dye is yellow and benzene is colourless.

[5]

15(a) The azo dye 'sunset yellow' is a food colouring, though its use is being phased out.



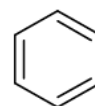
This dye can be made by a synthetic route that is shown, in outline, below.



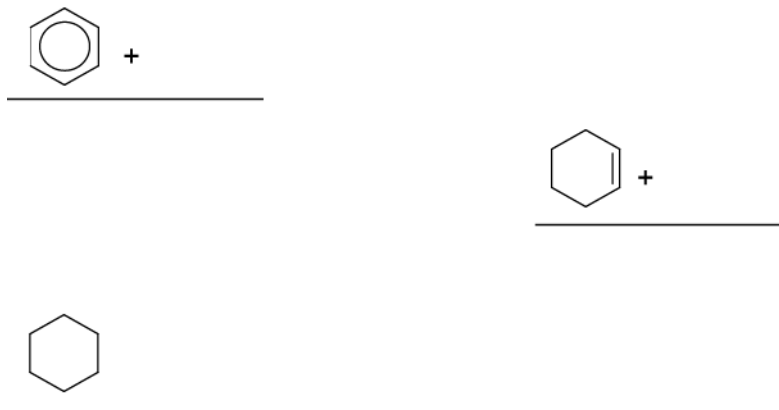
Complete the diagram by drawing the structure of compound **A**, and giving the reagents and conditions for the reactions.

[5]

(b) Enthalpy changes of hydrogenation show that benzene is **not** best represented as:



Complete and explain the energy level diagram below to show why this is so.



----- [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]

17(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.

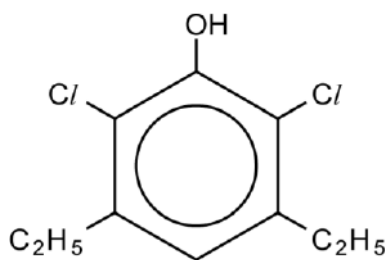
-----[1]

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

-----[2]

18(a) This question refers to the Advance Notice Article *Dettol* which accompanies this paper.

A chemist suggests using compound C, shown below, as an ingredient in an antiseptic such as dettol.



Compound C

- (i) Give the systematic name of compound C.

-----[1]

- (ii) Suggest, with a reason, **one** way in which compound C might be a better ingredient in dettol than the compound PCMX.

-----[1]

- (iii) Suggest, with reasons, **two** ways in which compound C might be a worse ingredient in dettol than the compound PCMX.

-----[2]

- (b) Explain why compounds with an aromatic ring usually form substituted derivatives, rather than addition compounds.

[2]

- (c) Suggest how PCMX binds to proteins.

[1]

- (d) PCMX is slightly more acidic than phenol. Suggest why this is so.

[2]

- (e) PCMX can dissolve in water and in non-polar solvents.

Name the intermolecular forces broken in the solvent in each case.

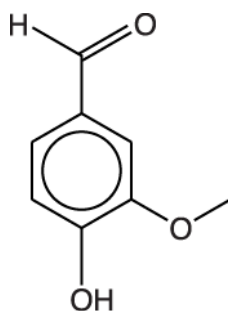
water -----

non-polar solvents -----

[2]

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.

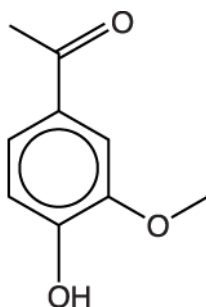
----- [2]

(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.

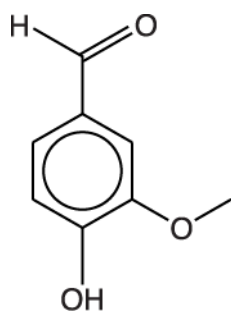


In your answer, you should use appropriate technical terms, spelled correctly.

[3]

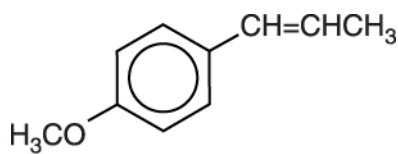
(c) Vanillin reacts with cyanide ions and dilute acid.

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]

(d) Anethole is only slightly soluble in water.

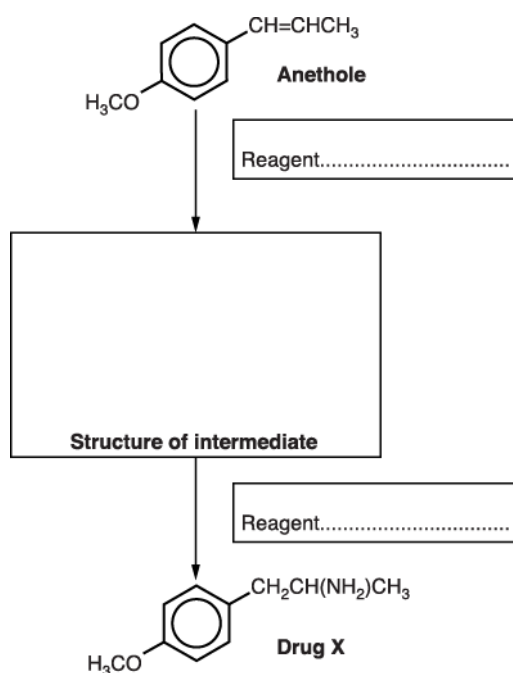
Explain this statement in terms of hydrogen bonding, indicating how these bonds are formed.

[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) Ancient paintings have been discovered in caves. The paintings were made using *ochre*, a natural pigment. Ochre owes its colour to the presence of $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$.

More recently, ochre has been used in oil paints. When ochre is used in oil paints it is suspended in oils such as linseed oil.

(i) Linseed oil is a triester of propane-1,2,3-triol.

Write an equation for the hydrolysis of this triester with KOH, using structural formulae for organic molecules. Represent the side chains as 'R'.

[3]

(ii) The carboxylate products from (i) are converted into methyl esters.

Draw the full structural formula of the methyl ester formed, representing the side chain as 'R'.

[1]

(iii) Give the laboratory reagents for the production of the ester in (ii) from its carboxylic acid.

reagents [1]

(b) The ester can be identified using gas-liquid chromatography.

For gas-liquid chromatography, give:

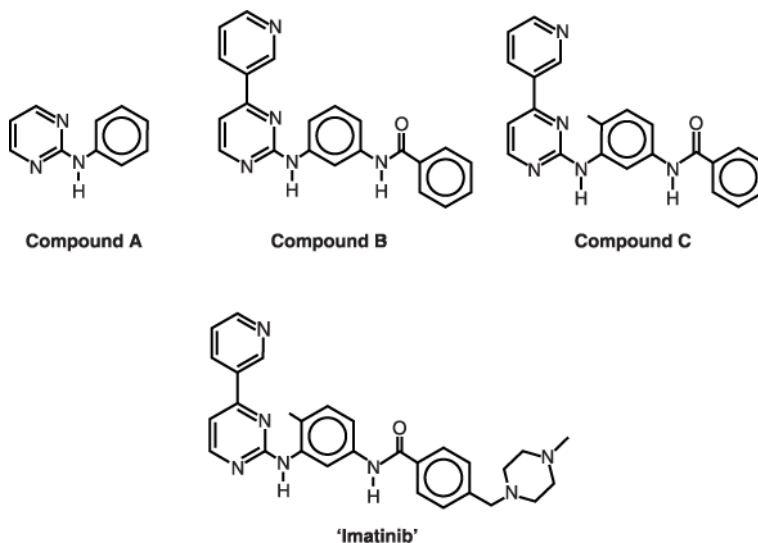
a suitable substance for the mobile phase

the nature of the stationary phase

the units of the x-axis of the chromatogram [3]

22(a) 'Imatinib' is a drug that was designed to combat leukaemia, a cancer of the blood. 'Imatinib' was developed as a result of work on three different compounds (A, B and C).

Compound A was found to have anti-leukaemia effects. Compound B was then found to be more effective and compound C more specific. 'Imatinib' was developed from compound C.



An extra group is added to compound C to make 'Imatinib' more soluble in water.

Suggest how the extra group does this.

-----[1]

(b) 'Imatinib' works by interfering with the function of an enzyme that only exists in cells affected by leukaemia. Thus the cells are unable to grow.

(i) All the compounds above have the same pharmacophore.

Draw a ring around the pharmacophore on the structure of 'Imatinib' above.

[1]

(ii) Suggest how this pharmacophore interferes with the function of the enzyme.

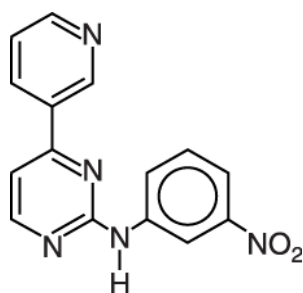
Suggest why compound C is more specific than compound B.



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

[4]

- (c) Compound **A** can be converted into another compound, **D**, shown below. This uses two reactions, one of which is nitration.



Compound D

- (i) Give the reagents and conditions for the laboratory conversion of benzene to nitrobenzene.

----- [2]

- (ii) Use the *Data Sheet* to **name** the reagents needed to convert the nitro group in compound **D** to an amine group. A new compound, **E**, is formed.

----- [1]

- (iii) Compound **E** is converted to compound **B** in a laboratory at room temperature.

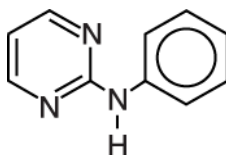
Name the functional group formed, and give the formula and name of a suitable reagent.

name of functional group formed -----

formula of reagent -----

name of reagent ----- [3]

(d) The structure of compound **A** is shown again below.

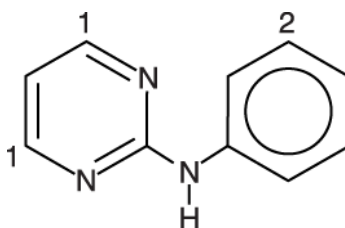


Compound A

(i) Write the molecular formula of compound **A**.

-----[1]

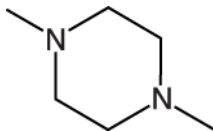
(ii) Indicate the number of peaks in the proton NMR of compound **A** by using numbers for each different proton environment on the structure below. Some numbers have been added already.



Compound A

[2]

(e)



The ring structure is not planar.

State a value for the bond angle and name the shape around the nitrogen atoms in the structure. Explain how this bond angle arises.

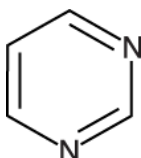
Draw a diagram to suggest a 3D shape for the ring.



In your answer you should make it clear how the points you make are linked together.

[5]

(f)



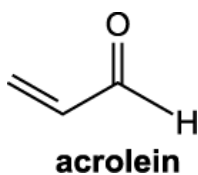
The ring structure is planar and has a similar electronic structure to benzene.

Suggest how the electrons are arranged in this structure.

[3]

23(a) The smell of burning fat is caused mainly by the presence of 'acrolein'. This is formed by the decomposition of propane-1,2,3-triol from the fat.

Acrolein is a colourless liquid that has many uses in organic chemistry.

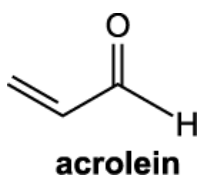


A sample of acrolein is tested for the presence of the aldehyde group using hot Fehling's solution.

Describe the colour **change** in this test.

Give the formula of the inorganic substance formed.

----- [3]



(b) HCN reacts with acrolein at the aldehyde group.

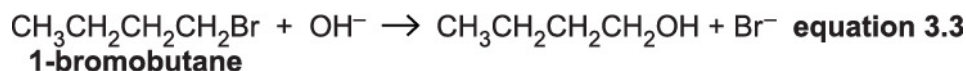
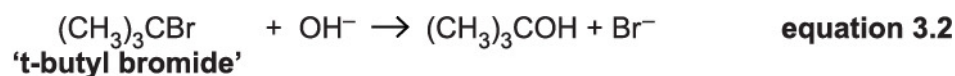
- (i) Draw the mechanism of the reaction of HCN with an aldehyde group.
Show full and partial charges and curly arrows.
Give the formula of the product.

[3]

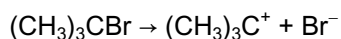
- (ii) Explain why the C=C bond would not be expected to react with HCN.

[2]

24 *t-butyl bromide and 1-bromobutane, an isomer, react with hydroxide ions as shown.



The reaction in **equation 3.2** has the rate-determining step shown below.



The reaction in **equation 3.3** occurs in a single step.

What can be deduced from this information about the mechanisms, orders of reaction and rate equations of the two reactions?

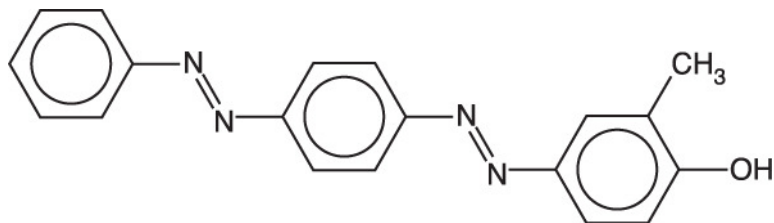
[6]

A electrophilic substitution
B nucleophilic addition
C electrophilic addition
D nucleophilic substitution

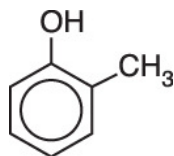
1

[1]

26 Which statement(s) about the dye shown below is/are correct?



- 1 It could be formed in a coupling reaction using the compound shown.



- 2 It is likely to be colourfast when bonded to polyester fibres.
3 It is insoluble in water.

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

Your answer

☐

[1]

27(a) A group of students decide to analyse a commercial sweetener.

The major component is listed as the dipeptide aspartame.

The students crush a sweetener tablet and dissolve it in 1 cm^3 of water in a test tube.

They add a similar volume of 6.0 mol dm^{-3} hydrochloric acid and some anti-bumping granules.

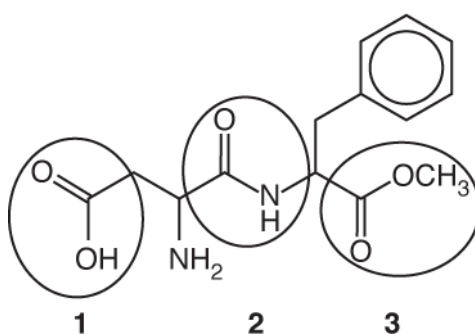
They then cautiously boil the contents for about a minute.

Suggest the purpose of adding the anti-bumping granules.

-----[1]

(b) The students expect the aspartame to have been hydrolysed by the hot acid.

(i) The structure of aspartame is given below with three functional groups (1, 2, 3) ringed.



Name the homologous series for the functional groups 1, 2 and 3.

1 -----

2 -----

3 -----

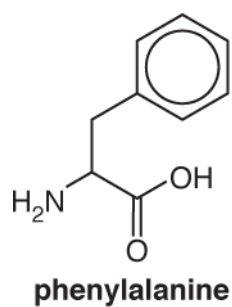
[1]

(ii) Functional group 2 and functional group 3 are hydrolysed under the acid conditions to give three products.

The products are methanol, and ions formed by the amino acids phenylalanine and aspartic acid.

The structure of the amino acid phenylalanine is given below.

In the box draw the structure of the **ion** formed by **aspartic acid**.



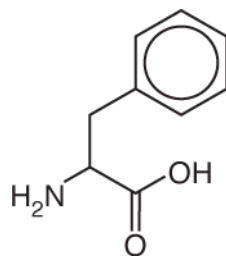
structure of **ion** formed by aspartic acid

[2]

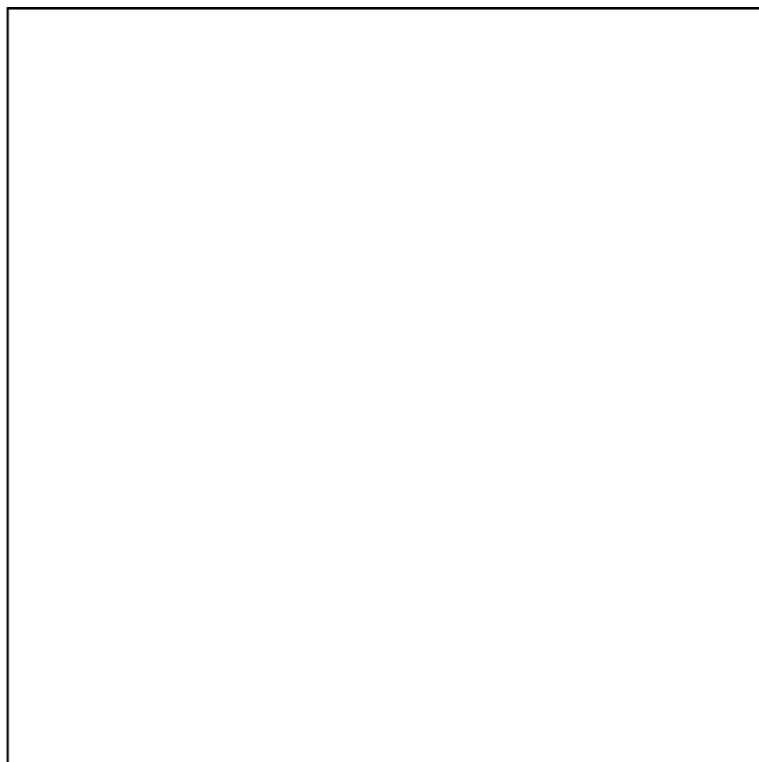
(iii) Amino acids such as phenylalanine exist as *zwitterions*.

Use the structure of phenylalanine to help explain how amino acids form zwitterions.

Draw the structure of the zwitterion of phenylalanine.



phenylalanine



[2]

(c)



The students wanted to confirm that the aspartame had been hydrolysed to produce the two amino acids, aspartic acid and phenylalanine.

They decided the best way was to use paper chromatography on the solution formed after the hydrolysis reaction.

Describe how the students could carry out the chromatography experiment and explain how they could use their results to show hydrolysis had taken place.

You may include a diagram in your answer.

[6]

- Suggest why regular cola keeps for longer.

[2]

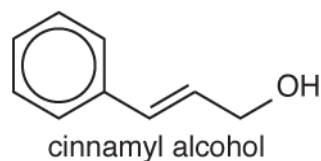
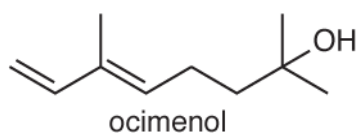
- A high volatility
- B high solubility in the stationary phase
- C high affinity for the mobile phase
- D non-polar molecules

7

[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.



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

.....

oxidising agent + cinnamyl alcohol

heat

cold water

technique used

.....

homologous series of product

.....

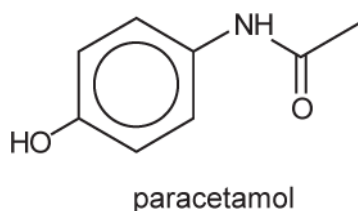
[4]

(b) Ocimenol and cinnamyl alcohol are both unsaturated molecules.

Explain how you could use a solution of bromine water to show which of the molecules has the greater degree of unsaturation.

[4]

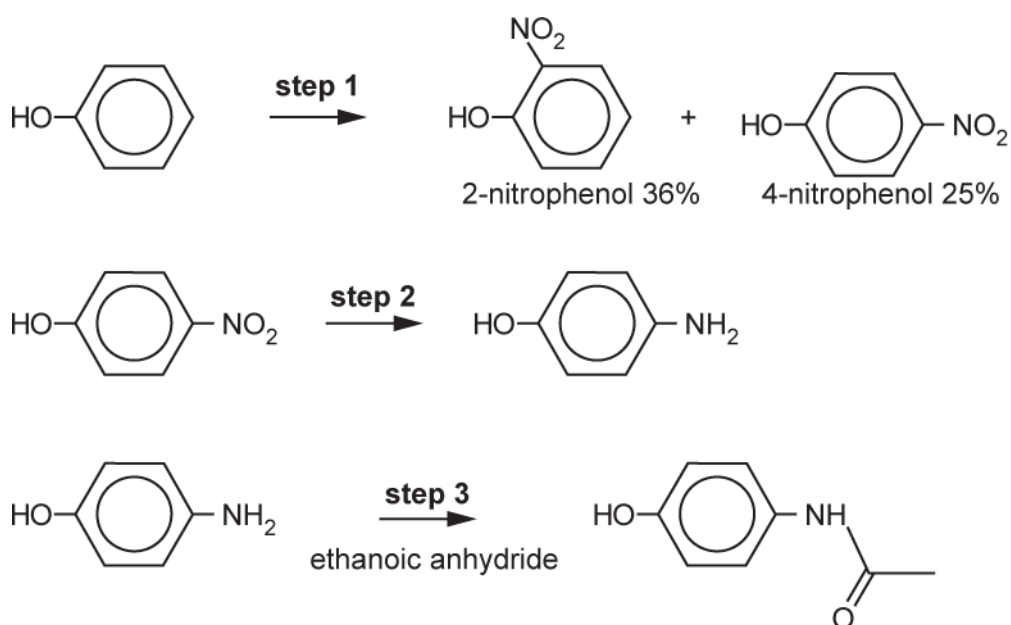
30(a) Paracetamol is a pain-relieving medicine.



Name **two** functional groups in paracetamol, apart from the benzene ring.

----- [2]

(b) Some students set out to make paracetamol by the method shown below.



(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]

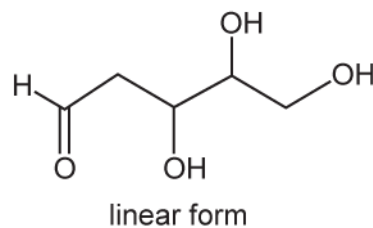
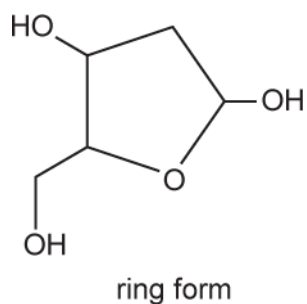
- (v) The students purify the product from **step 3** by recrystallisation from water.

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

[4]

31(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]

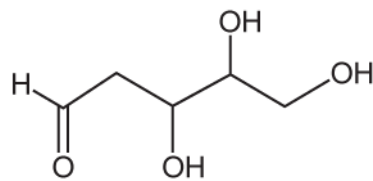
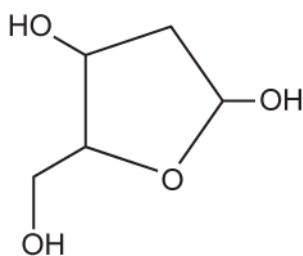
(ii) Name the functional group that is present in the linear form only.

-----[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.

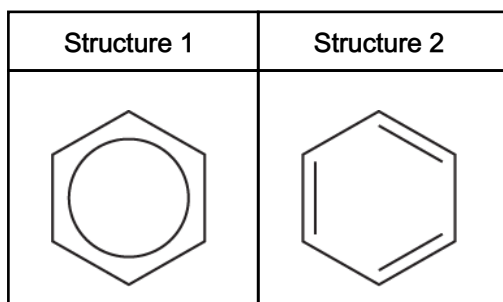
A sugar-phosphate backbone is formed.

Draw a section of the sugar-phosphate backbone.

Show one deoxyribose and two phosphate groups.

[2]

32(a) Two possible representations for benzene (C_6H_6) are shown below.



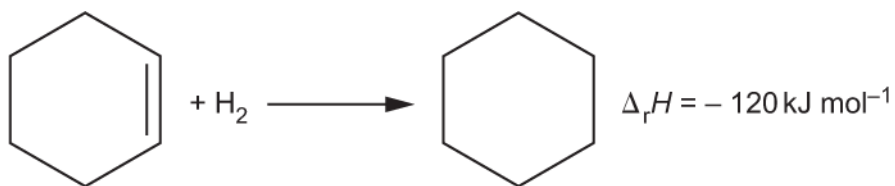
(i) Compare and explain the bond angles and bond lengths predicted by each structure.

Bond angles

Bond lengths

[4]

(ii) The equation below shows the hydrogenation of cyclohexene.

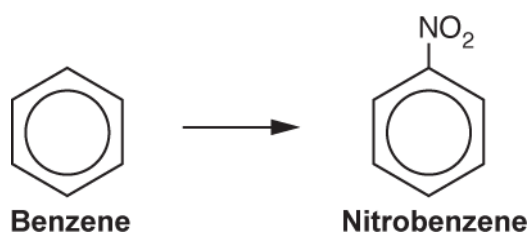


When benzene is reacted with hydrogen to form cyclohexane the enthalpy change is found to be -208 kJ mol^{-1} .

Explain why this data supports structure 1 rather than structure 2.

[2]

(b) A student wants to synthesise a dye. The first step in the formation of the dye is shown below.



(i) This is an electrophilic substitution reaction.

Give the conditions for the reaction and an equation to show how the electrophile is formed.

Conditions -----

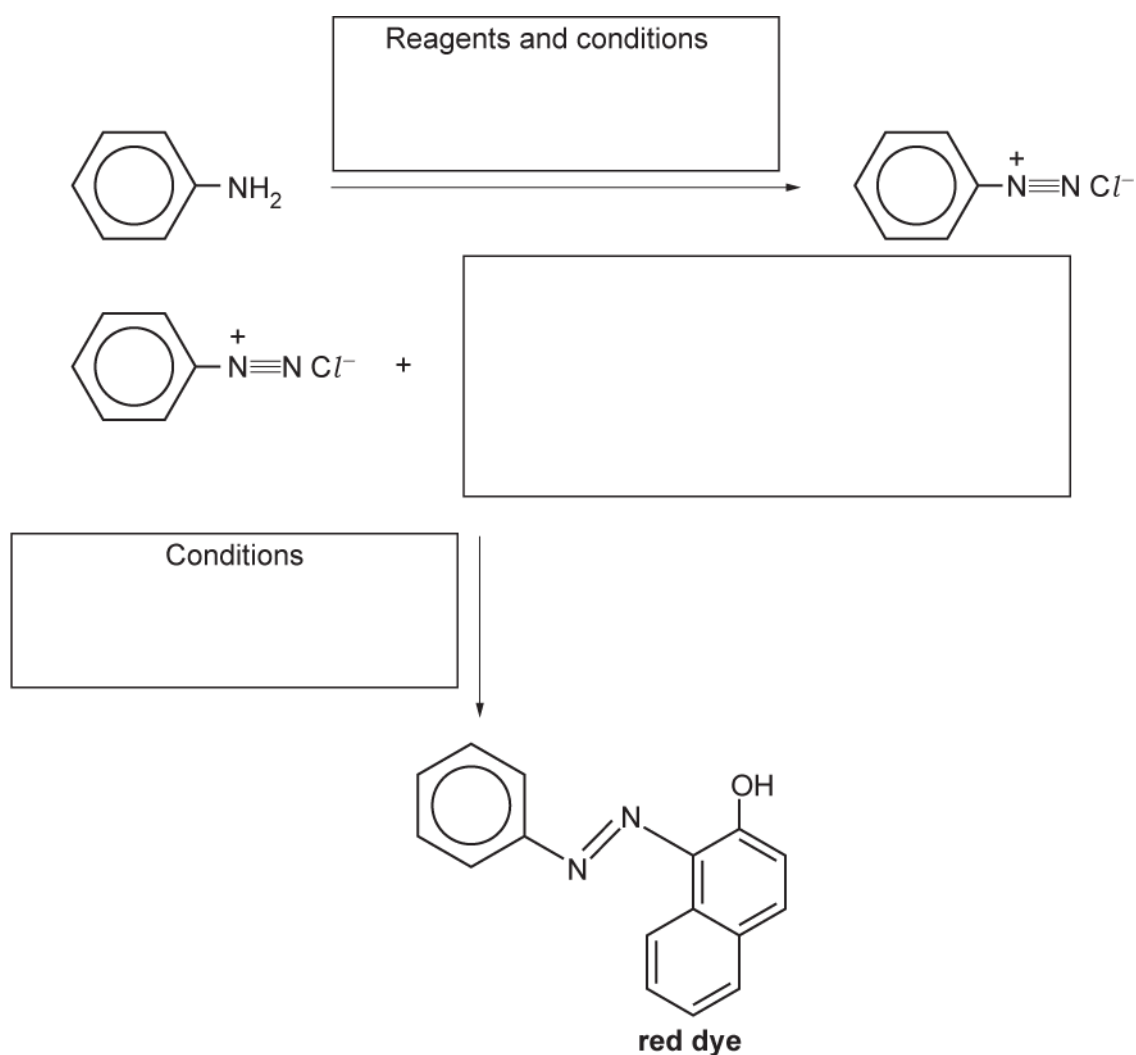
Equation for formation of the electrophile

[2]

(ii) The nitrobenzene is then changed to phenylamine.

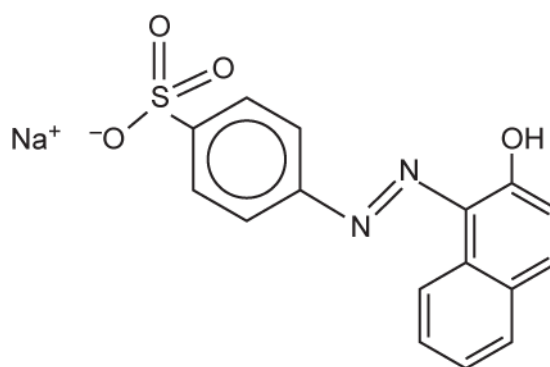
The flow diagram shows how the student could produce the red dye shown from phenylamine.

Complete the diagram by filling in the boxes.



[4]

- (c) The dye produced is not very soluble in water.
In order to increase its solubility it is converted to the structure below.



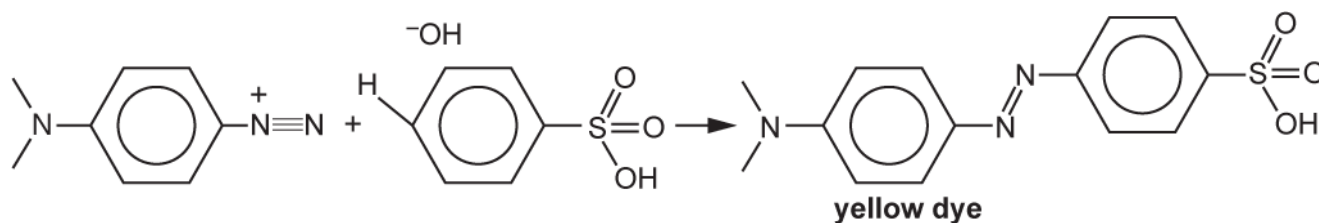
Name the -SO_3^- group.

[1]

- (d) A dye is used as an acid-base indicator. It is red in acidic conditions and yellow in neutral or alkaline conditions.

The equation for the reaction producing the yellow form of the dye is shown below. It is carried out in alkaline conditions.

Add curly arrows to the equation to show the mechanism of the reaction forming the dye.



[3]

- (e) The indicator dye is a weak acid and may be described as HIn.
For the reaction shown below, $K_a = 1.6 \times 10^{-4} \text{ mol dm}^{-3}$.



This indicator changes colour at pH 3.7.

Find the ratio $[\text{In}^-] / [\text{HIn}]$ when it changes colour.

$$[\text{In}^-] / [\text{HIn}] = \text{-----} \quad [2]$$

This question is based on the article **Saving paper** from *Education in Chemistry*, March 2013, published by the Royal Society of Chemistry which comes as an insert with this paper.



- (i)  Lignin contains chromophores that absorb in the uv, whereas the decomposition products look yellow.

Explain what affects the frequency of radiation absorbed and why the decomposition products look yellow.

This image shows a blank sheet of white paper with horizontal dashed lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no other markings or text on the page.

(ii) Calculate the energy (in kJ mol^{-1}) that corresponds to a wavelength of 350 nm absorbed by lignin.

(1 nm = 10^{-9} m)

energy = ... kJ mol^{-1} [3]

- 34 An unsaturated carboxylic acid has an M_r of 280.
70 g of the acid is saturated by 1.0 g of hydrogen.

How many C=C bonds are there in one molecule of the acid?

- A 1
B 2
C 4
D 8

Your answer

[1]

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

A $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$

B $(\text{CH}_3)_3\text{COH}$

C CH_3COOH

D CH_3COCH_3

Your answer

[1]

36 Which statement/s is/are a result of delocalisation in benzene?

1 Benzene undergoes substitution reactions.

2 Benzene reacts faster with bromine than alkenes do.

3 The enthalpy change of hydrogenation of benzene is three times that of cyclohexene.

A 1, 2 and 3

B Only 1 and 2

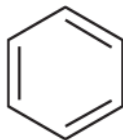
C Only 2 and 3

D Only 1

Your answer

[1]

37 Kekulé represented benzene as:



Which statement/s follow/s from this structure?

1 All the carbon-carbon bonds are of equal length in benzene.

2 The C–C–C bond angle in benzene is 120° .

3 Benzene has a planar structure.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer

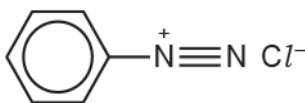
☐

[1]

38(a)

A student decides to use a microscale method to synthesise an azo dye and dye a fabric.

The student initially makes a small amount of a solution of the diazonium compound shown below, starting from an aromatic amine.



benzenediazonium chloride

Name the reagents and conditions needed to make this compound.

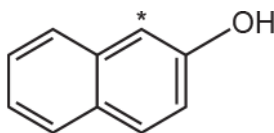
Reagents

Conditions

----- [3]

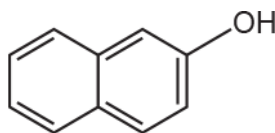
- (b) Naphthalen-2-ol, shown below, is used to make the dye. A piece of cotton is dipped into naphthalen-2-ol dissolved in sodium hydroxide. The benzenediazonium solution is then added to dye the cotton red.

The coupling reaction involves the carbon atom marked with an asterisk, *.



naphthalen-2-ol

- (i) Complete the structure of the azo dye formed in this coupling reaction.



[1]

- (ii) The azo dye formed above has an extended delocalised system.

[4]

[4]

- (i) Give **one** property of the dye that might be affected if nitro, NO_2 , groups are attached.

[1]

-
- [1]

[1]

Cyclohexene is an industrially important alkene.

- (i) Explain how the enthalpy change of hydrogenation of cyclohexene is used to give evidence for the bonding in the benzene molecule.

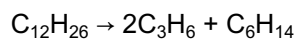
[3]

- (ii) *Cyclohexene and benzene both react with bromine but in different ways.

Compare the two reactions and explain why they are different.

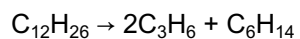
[6]

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**.



Equation 31.1

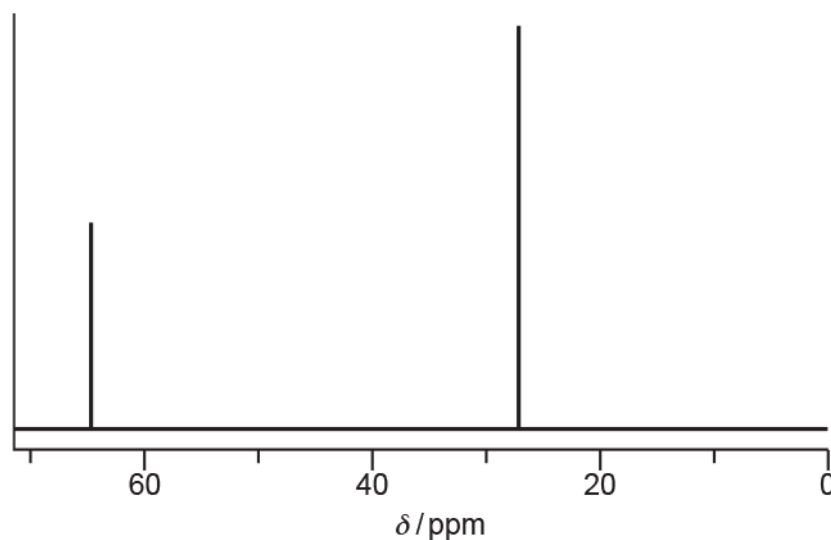
The propene produced in **equation 31.1** has many uses in the chemical industry.



Equation 31.1

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

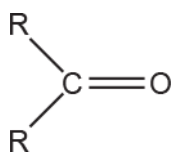
[1]

- (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.

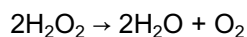
Give the mechanism for the reaction of this compound with cyanide ions followed by H^+ .
Show curly arrows, relevant dipoles and charges and give the formula of the product.

Name the type of reaction.



type of reaction [4]

- 41 Why does human hair turn grey? Studies have shown that this is caused by lower levels of the enzyme catalase in hair follicles. Catalase catalyses the breakdown of hydrogen peroxide as shown in equation 3.1.



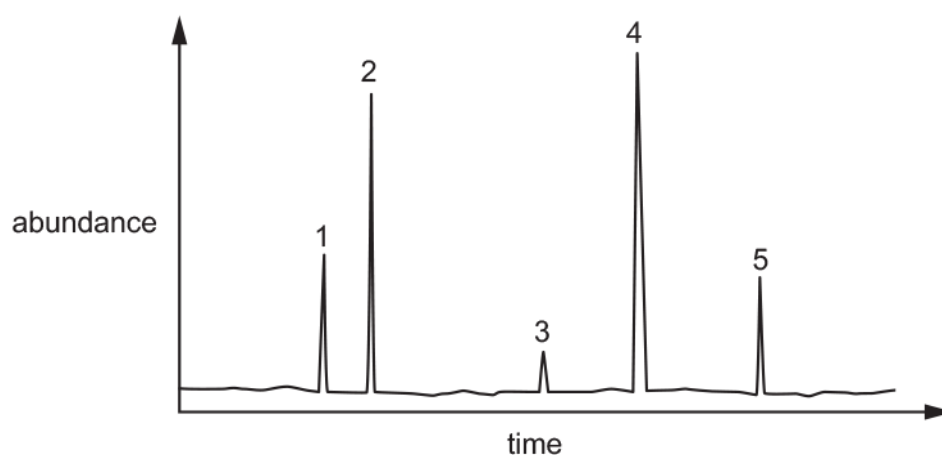
Equation 3.1

When levels of hydrogen peroxide increase, the melanin (dye) in the hair is bleached.

Suggest the **type** of reaction by which hydrogen peroxide bleaches melanin.

-----[1]

- 42 The diagram below shows a gas chromatogram.



Which statement about the gas chromatogram is correct?

- A The mixture consisted of at least 5 different substances.
- B Substance 5 came out of the column first.
- C Substance 1 had the greatest affinity for the stationary phase.
- D Substance 5 had the greatest affinity for the mobile phase.

Your answer

[1]

43 One of the products of the reaction of ozone with unburned fuel from car exhausts is $(\text{CH}_3)_3\text{CCH}_2\text{CH}(\text{CH}_3)\text{CHO}$.

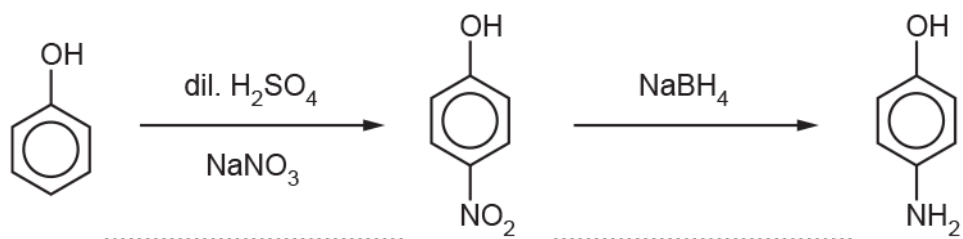
(i) Name the functional group in $(\text{CH}_3)_3\text{CCH}_2\text{CH}(\text{CH}_3)\text{CHO}$.

-----[1]

(ii) Give the equation for the reaction of HCN with the functional group identified in (f)(i).

[1]

44(a) The reactant 4-aminophenol can be made from phenol in the two-step synthesis shown below.



Name the **type** of reaction for each step.

Write your answers on the dotted lines.

[2]

(b) Fig. 2.2 shows some information found on a bottle of ethanoic anhydride.

The students use the information in Fig. 2.2 to write a risk assessment for ethanoic anhydride.

Ethanoic anhydride	Hazards
	Flammable Harmful by inhalation and if swallowed Corrosive – causes burns

Fig. 2.2

Suggest **three** precautions that the students should take when using ethanoic anhydride.

1

.....

2

.....

3

.....

[3]

(c) The mechanism for the reaction for the formation of paracetamol is shown in Fig. 2.3.

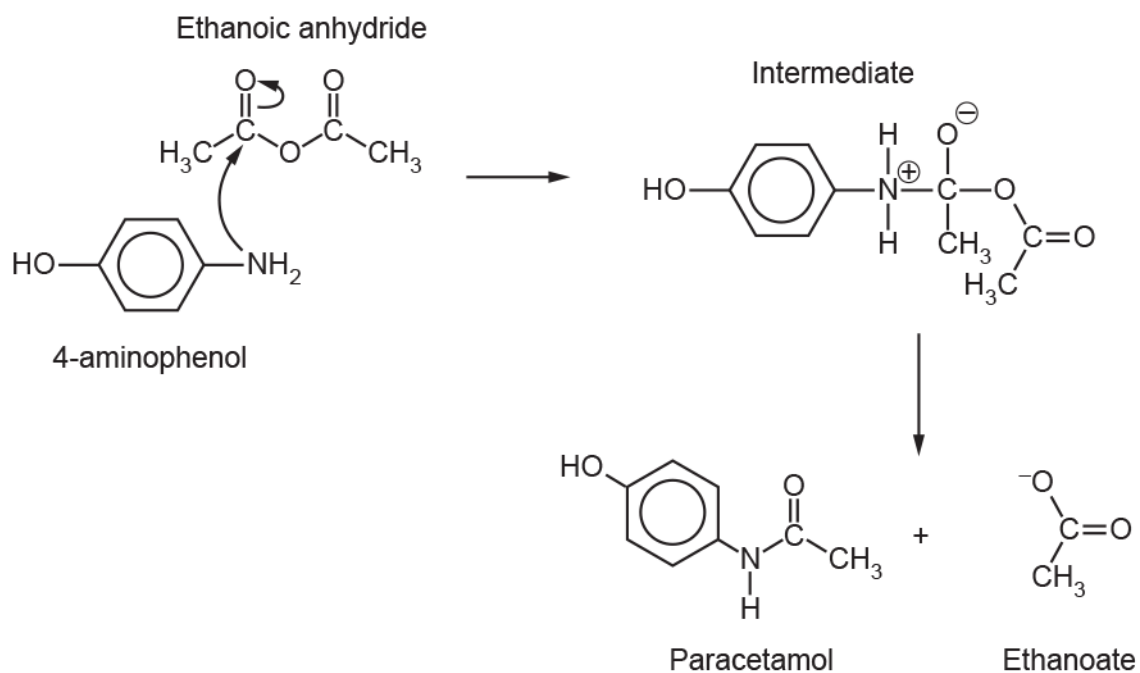


Fig. 2.3

Mark curly arrows to show the electron movements that occur in the **intermediate** to allow formation of the products in Fig. 2.3.

[1]

45 What is the functional group in $\text{C}_6\text{H}_5\text{COCH}_3$?

- A Aldehyde
- B Carboxylic acid
- C Ester
- D Ketone

Your answer

[1]

46 Which statement about gas-liquid chromatography is correct?

- A The column consists of a low boiling liquid on a porous support.
- B The compound with the longest retention time comes out first.
- C The emerging compounds can be detected by mass spectrometry.
- D The sample does not need a carrier gas.

Your answer

[1]

47 Which compound(s) can be made from benzene in one step?

- 1 $\text{C}_6\text{H}_5\text{Cl}$
- 2 $\text{C}_6\text{H}_5\text{NO}_2$
- 3 $\text{C}_6\text{H}_5\text{NH}_2$

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

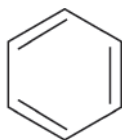
Your answer

[1]

48 Benzene can be represented as structure **V** or as structure **W** as shown below.



structure V



structure W

Which of the following statement(s) is / are evidence for structure **V** rather than structure **W**?

- 1 The carbon – carbon bond lengths are all the same in benzene.
- 2 The bond angles are all the same in benzene.
- 3 The enthalpy change of hydrogenation of benzene is three times that of cyclohexene.

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

Your answer

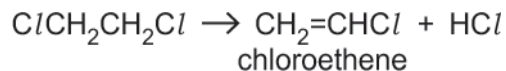
[1]

49(a) Chloroethene is made in an industrial cracking reaction and is the monomer for making poly(chloroethene).

Chloroethene can be made from ethene in two steps:

Step 1 is the formation of $\text{C}/\text{CH}_2\text{CH}_2\text{C}/$ from ethene.

Step 2 is thermal cracking of $\text{C}/\text{CH}_2\text{CH}_2\text{C}/$ to eliminate HCl .



The $\text{C}/\text{CH}_2\text{CH}_2\text{C}/$ produced in **step 1** can also be used to make other substances.

(i) Give the systematic name for $\text{C}/\text{CH}_2\text{CH}_2\text{C}/$.

----- [1]

(ii) $\text{C}/\text{CH}_2\text{CH}_2\text{C}/$ can be converted to $\text{HOCH}_2\text{CH}_2\text{OH}$ by refluxing with sodium hydroxide solution.

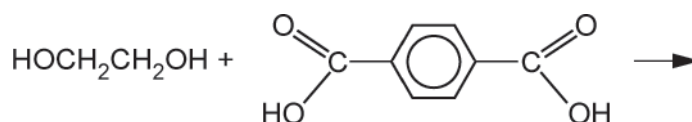
Name the mechanism for this reaction.

----- [1]

(iii) The $\text{HOCH}_2\text{CH}_2\text{OH}$ and a dicarboxylic acid are reacted together to make another polymer.

Complete the equation for the reaction below.

Show one repeat unit of the polymer.



[2]

(b) * Propene is produced by a cracking reaction.

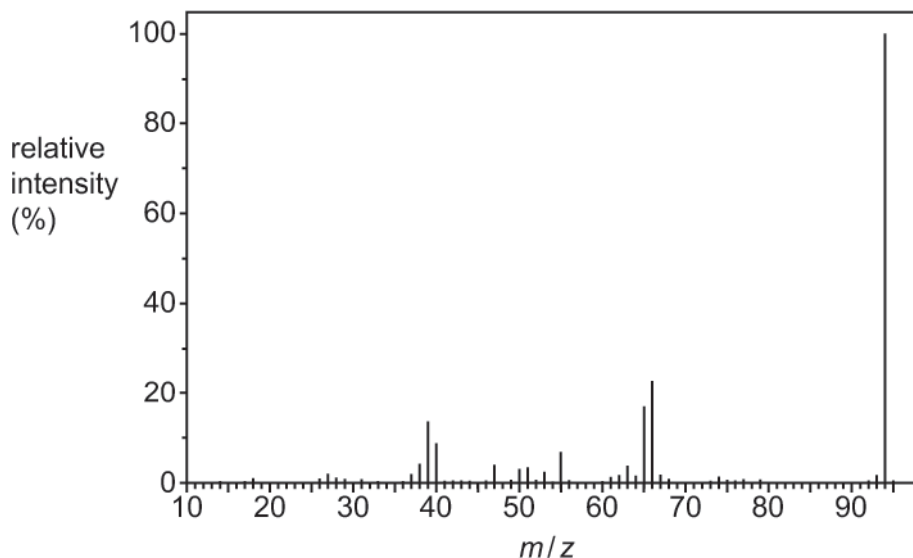
Propene can be reacted with benzene in the presence of oxygen to produce two useful products, **A** and **B**.

A student did sortie 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.

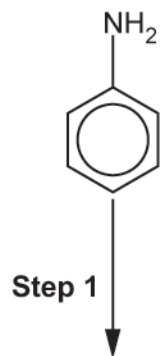
Blank lined paper for writing.

50(a) Some students want to synthesise dyes that will bind well to wool fibres.

They read that they can make coloured molecules using coupling reactions between phenols and diazonium ions.

The students synthesise **dye C**, shown below, in two steps.

Complete the reaction sequence by filling in the boxes.



Reagents for **step 1**: $\text{NaNO}_2 + \text{HCl}$

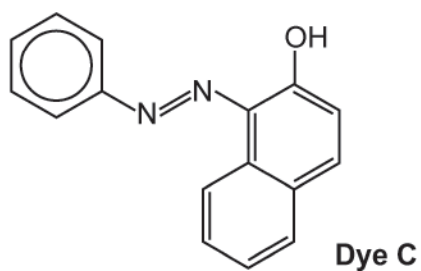
Conditions:

.....

Product of **step 1**:

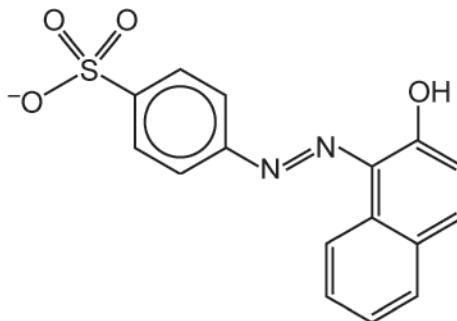
Step 2

Reagent for **step 2**:



(b) **Dye C** can be modified to form the more useful dye **D**, shown below.

[3]



Dye D

- (i) Suggest a reagent and the conditions that would turn **dye C** into **dye D**.

----- [1]

- (ii) Comment on the solubility of the two dyes in water.

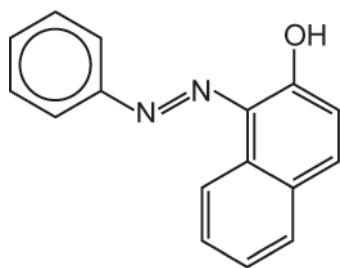
In your answer consider intermolecular bonds and their relative strengths.

Solubility of dye C -----

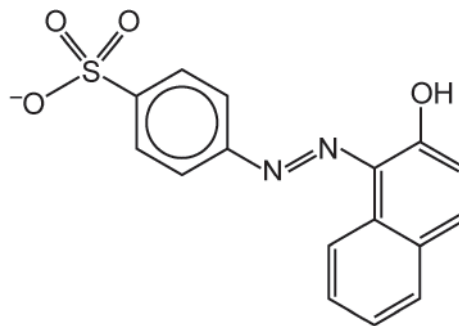
Solubility of dye D -----

[3]

(c) Dye C and dye D are shown.



Dye C



Dye D

Dye C has an orange colour.

(i) Explain why dye C absorbs visible light.

[3]

(ii) How is the colour of the light absorbed related to the light seen?

[1]

(d) Wool is based on protein structures.

Explain how **dye D** might bind to the wool fibres in weakly acidic conditions.

----- [2]

- 51 '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.

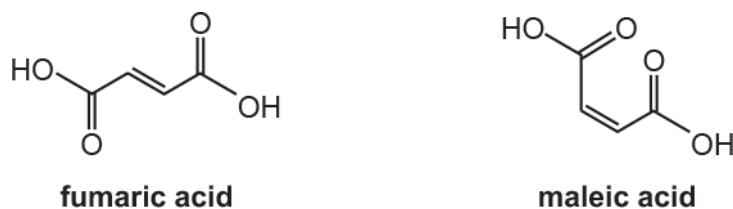


Fig. 4.1

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.

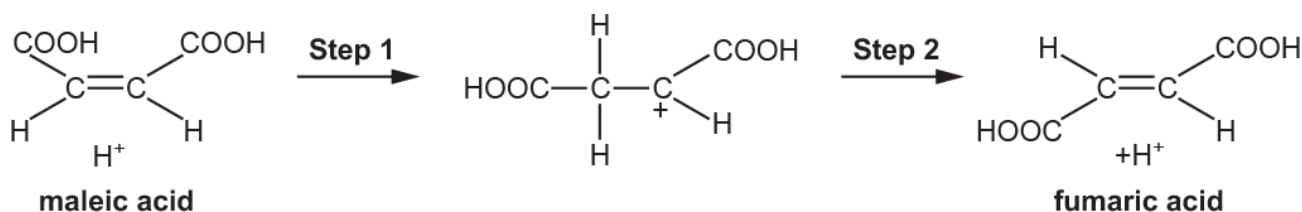


Fig. 4.2

[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.

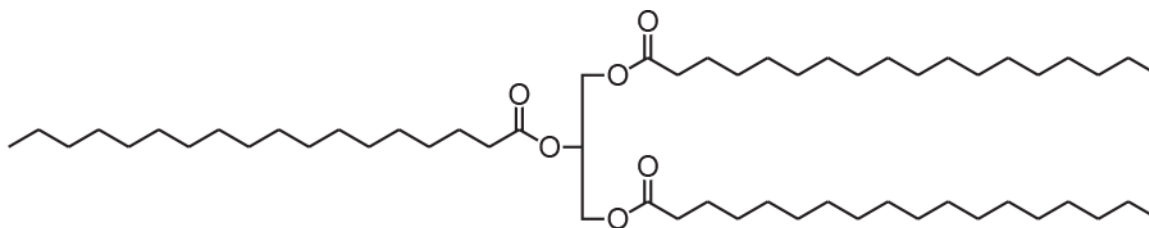
Does this support the student's mechanism in Fig. 4.2?

Explain your answer.

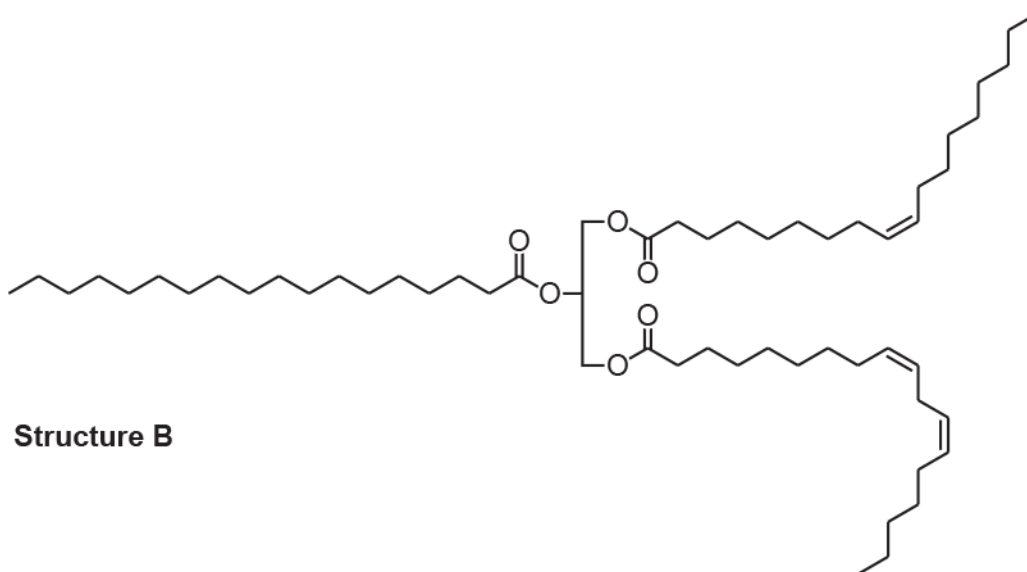
-----[2]

Most fats and oils are triesters formed from the reaction of propane-1,2,3-triol (glycerol) with long chain carboxylic acids (fatty acids).

Two triesters **A** and **B** are shown below.



Structure A



Structure B

- (i) Structure **B** is described as a 'cis' unsaturated oil.

Explain the meanings of 'cis' and 'unsaturated'.

[2]

- (ii) State the types of intermolecular bonds between molecules of both structures and describe where in the molecules they occur.

[2]

- (iii) Suggest why Structure A is more likely to be a solid at room temperature than Structure B.

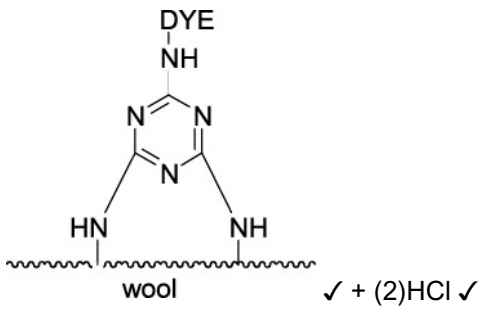
[3]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		$\text{SO}_3^-(\text{Na}^+)$ ✓ ion(-)dipole bonds / interactions (with water) ✓ OR OH / NH ✓ form hydrogen bonds (with water) ✓	2	ALLOW groups marked on formula of dye IGNORE names for first mark ALLOW ion-dipole bonds or ion attraction to $\text{H}^{\delta+}$ described Second mark depends on first being scored except... 'alcohol' is CON to OH for first mark but second mark can still be considered Correct name (sulfonate, phenol / hydrox(l), (secondary) amine) allows second mark of pair to be scored Examiner's Comments Most candidates could give the formula of one of the possible groups and name its interaction with water molecules.
	b	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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	react with (hydrogen)carbonates / formulae ✓ effervescence / fizz / give gas / give CO ₂ ✓	2	ALLOW any carbonate (eg CaCO ₃) <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.
	c	i		2	Mark separately Structure must be correctly copied ALLOW N–H for 'NH' and carbon atoms shown Examiner's Comments Many candidates could draw the correct structure and very few omitted HCl as a product. Many of the errors were careless – for example poor copying of the dye structure, or omission of the hydrogen atoms on the lower N atoms.

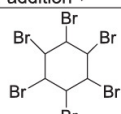
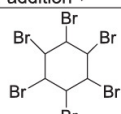
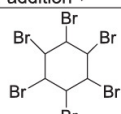
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	dye is 'fast' in water / dye does not run when washing / dye is not washed out / dye stays / dye lasts longer / does not dissolve AW ora ✓ covalent bonds not broken by / in water / covalent bonds not made between dye and water ✓ hydrogen bonds are broken by / in water / hydrogen bonds made between dye and water ✓	3	ALLOW 'colour' for 'dye' IGNORE 'fading' IGNORE 'dye will not form hydrogen bonds with water' to score either of the second two marking points, there must be a clear implication that water is involved, i.e.: IGNORE 'covalent bonds are stronger than hydrogen bonds' Examiner's Comments This was a test of accurate expression of ideas which some candidates passed well. Candidates had to say that the dye would not 'wash out' (not 'fade') because water (not 'washing') would not break covalent bonds. Water could form hydrogen bonds with the dye that linked to wool by these bonds. Errors of expression included hydrogen bonds making hydrogen bonds with water or water hydrogen bonding with wool.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		1. Electron(s) excited to / move to higher energy level ✓ 2. $\Delta E = h\nu$ / frequency absorbed related to energy gap ✓ 3. Light / visible (radiation) is absorbed ✓ 4. size of ΔE / frequency / wavelength depends on: EITHER length of / size of / bonding in / functional groups in chromophore OR amount of delocalisation ✓ 5. complementary colour transmitted / reflected ✓	5	ALLOW 'state' for 'level' IGNORE 'shell' Do not award this mark if in terms of d electrons In 2. ALLOW $E = h\nu$ only if energy <i>change</i> is clear ALLOW 'gap between energy levels' for 'ΔE' ALLOW 'hf' for '$h\nu$' ALLOW 'excitation energy' for ΔE NOT 'electrons falling' in connection with any radiation given out (only mpts 2. and 4. can be considered) QWC: only award 5. if 3. scored OR 'frequency absorbed' stated ALLOW 'complimentary' IGNORE 'emission' ALLOW 'colours / frequencies / wavelengths not absorbed' for 'complementary colour' Examiner's Comments By contrast, this much more familiar question was answered well. Many candidates could describe the origins of colour in dyes and link the difference in ΔE to the size of the chromophore. There was still a minority who think the colour comes from the electrons dropping, so presumably they would expect dyes to glow in the dark.

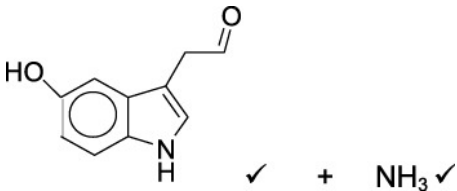
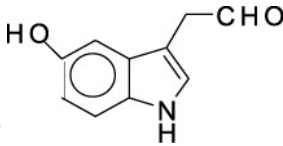
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance									
e	i		<table><tr><td></td><td>Structure C</td><td>Structure D</td></tr><tr><td>Type of reaction</td><td>substitution ✓</td><td>addition ✓</td></tr><tr><td>Skeletal formula of organic product</td><td></td><td> OR </td></tr></table>		Structure C	Structure D	Type of reaction	substitution ✓	addition ✓	Skeletal formula of organic product		 OR 	4	IGNORE 'electrophilic' or 'bromination' in 'type' boxes but 'nucleophilic' is CON to either or both ALLOW di or tri bromination of C ALLOW D with two double bonds brominated or brominated at 1,4. ALLOW substituted Kekulé benzene in lower left box IGNORE names and molecular and non-skeletal formulae IGNORE '+HBr' in bottom left box Examiner's Comments This question was well-answered, with many candidates scoring all the marks. Common errors were just one bromine atom on the right-hand structure or 1,3,5-tribromocyclohexane.
	Structure C	Structure D												
Type of reaction	substitution ✓	addition ✓												
Skeletal formula of organic product		 OR 												
	ii		different (bond) lengths ✓ double bonds are shorter than single bonds ✓	2	Second marking point also scores first Examiner's Comments Most candidates stated that the bond lengths would be different and almost all said that double bonds were shorter than single bonds.									
f	i		$\text{C}_6\text{H}_6 + \text{Cl}_2 \xrightarrow{\text{Fe/FeCl}_3/\text{AlCl}_3} \text{C}_6\text{H}_5\text{Cl} + \text{HCl}$ equation ✓	2	mark separately IGNORE state symbols ALLOW any suitable structures for substances ALLOW catalyst formula over arrow in the question stem IGNORE (for second mark) names of catalysts and 'anhydrous' or 'reflux' or 'heat' Other reagents above or below arrow are CON Examiner's Comments Many candidates could write a correct equation and give the formula of a suitable catalyst, usually AlCl₃. Some did not realise that HCl was also formed.									

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	NaOH / sodium hydroxide ✓	1	ALLOW any group 1 hydroxide IGNORE water / H₂O Examiner's Comments The answer 'sodium hydroxide' (or its formula) was given by many candidates. Some thought that water was a powerful enough nucleophile to undertake this reaction.
			Total	26	
2		i	 two arrows on left-hand structures ✓ intermediate ✓ two arrows on intermediate ✓ Award one mark for one correct arrow on reactant and one on intermediate if there are no incorrect arrows (other detail can be incorrect)	3	curly arrows must start on correct atom, bond or charge (if projected backwards) and end pointing at correct bond or atom. (Left-hand arrow can either point to C or the line between the lone pair and C) ALLOW arrow from '-' sign on RO⁻: ALLOW right-hand arrow starting from a drawn lone pair on -O⁻ Do not allow 'half arrows' (fish-hooks) the first time encountered, but allow by ecf subsequently. IGNORE partial charges
		ii	nucleophile ✓	1	Examiner's Comments Some candidates scored more than one mark by realising that the intermediate was an anion with the negative charge on the oxygen. Only a few were able to draw all the curly arrows correctly.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3	a		Benzene / A undergoes substitution (more easily than addition) ✓ mention of delocalised electrons (in A) ✓ Benzene / A does not undergo addition (readily) ✓ because it has no double bonds / alkene ✓ OR B undergoes addition ✓ because it has double bonds / alkene ✓	4	IGNORE references to mechanism or products IGNORE references to stability or bond length QWC (in second set of two marks) only award addition mark if mention of double bonds. Addition must be mentioned not just implied Examiner's Comments This was similar to other questions of its type but did focus on <i>reactions</i>. Those who talked about bond lengths still usually scored the marks in the end, though some candidates did not mention addition and substitution at all.
	b			2	 ALLOW or any correct structural formula including mixtures of structural and skeletal Examiner's Comments Many scored the mark for the structure of the aldehyde and even more for deducing that ammonia was the other product. The commonest error was failure to copy correctly the unchanged part of the serotonin structure, which was a shame.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		1. (substrate is) serotonin ✓ 2. moclobemide / inhibitor binds with active / receptor site AW ✓ 3. (moclobemide) blocks (the active / receptor site) OR (moclobemide) competes with the substrate OR substrate cannot bind (as well)/enzyme-substrate complex cannot form (as well) ✓ OR fewer / less active sites available for substrate 4. (increased serotonin / substrate concentration allows) increased rate ✓	4	ALLOW '(CH₂)NH₂ group of serotonin' ALLOW 'bonds', 'fits', 'forms complex' instead of 'binds' in 2. ALLOW 'serotonin' for substrate or ecf on substrate name from 1. IGNORE moclobemide reacting with substrate IGNORE reasons Examiner's Comments This was usually well done with most using their chemical comprehension to realise that serotonin was the substrate and to explain why moclobemide was an inhibitor. The last part required understanding of enzyme kinetics and equilibrium to realise that the rate would increase with the substrate concentration.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		1. electrons move up(AW) energy levels✓ 2. light / radiation is absorbed (with frequency related to energy gap by) $\Delta E = hv/hf$ ✓ 3. complementary colour / frequency... OR colours / frequencies not absorbed... ...are reflected / transmitted ✓ 4. phenelzine has small(er) chromophore / less delocalisation (therefore) larger ΔE / energy gap / ν / frequency (ora for coloured / 'aromatic' molecules)✓ 5. uv has higher frequency / higher energy (than visible light) ora ✓	5	reference to d electrons is CON to this mark only IGNORE 'E=hv' unless 'energy gap / difference' mentioned in close proximity ALLOW 'frequency proportional to energy gap' accept the two parts of 2. if they are separated in the answer. ALLOW 'complimentary' Any reference to electrons falling and giving out / emitting light CONS 3. 4. may be split through answer This can be scored if a reference to phenelzine absorbing in uv immediately follows the second part of 4.('larger ΔE / energy gap / ν / frequency') Examiner's Comments Much of this question was familiar territory and many scored the first three marking points, which dealt with the general origins of colour in organic compounds. Some failed to tie together the idea of the energy gap being proportional to the frequency of light absorbed. The number talking about electrons emitting light when falling was smaller this year. The last two marking points required understanding of the fact that uv radiation had a higher frequency than light and that phenelzine had a smaller chromophore, and thus the energy gap was bigger.
			Total	15	

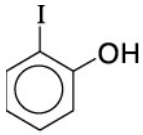
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	propene ✓	1	NOT prop-1-ene
		ii	similarity: C-C bond formed / C atom attached to benzene OR alkylation OR hydrocarbon (chain)(AW) attached / substituted / added ✓ difference: no use of halogen compound OR only one product / no HC/ (or H⁺) formed / lost ✓	2	IGNORE references to alkenes as reactants ALLOW 'eliminated' Examiner's Comments Most named the compound correctly as propene and many could compare the reaction with a normal Friedel Crafts reaction.
	b	i	1. more / greater / higher yield OR more / greater amount of compound B / product ✓ 2. fewer molecules / particles / moles on right-hand side / product <i>ora</i> ✓ 3. molecules / particles.... in smaller volume / space (not area) OR ...closer together OR ...more concentrated AW ✓ 4. greater frequency of collisions AND faster rate (of reaction) AW ✓	4	IGNORE 'equilibrium moves to the right' unless it indicates which side has fewer moles QWC marking point 1 depends on marking point 2 being scored 'molecules have increased energy' CONs this point marking points 3 and 4 can be marked separately 4. frequency must be implied (not just 'more collisions') IGNORE 'chance of collision' Examiner's Comments Was the physical part and many scored full marks. Errors in part (i) included a failure to say which was the side with fewer moles, that the concentration of the particles was greater and that the frequency of collisions was greater.

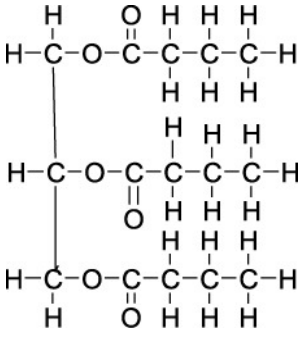
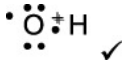
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Forward) reaction exothermic (ora) AND equilibrium constant smaller AW ✓ Rate (too) slow(er)/takes too long to reach equm below 250 AW ✓	2	IGNORE 'equilibrium moves to the left' but 'equilibrium moves to left (AW) in endothermic direction' will score first part of marking point. IGNORE 'compromise' Examiner's Comments Most scored the marks.
		iii	100% ✓ no waste (product) (to be disposed of) ✓	2	IGNORE 'high' IGNORE reference to toxic / harmful NOT 'no by-product' Examiner's Comments This showed a good understanding of atom economy. The rare error was to hedge bets by saying 'less waste', rather than 'no waste'.
	c	i	2-hydroxy-2-methylpropan(e)nitrile / (propanone) cyan(o)hydrin ✓ HCN / KCN / NaCN ✓	2	IGNORE dashes, commas and spaces ALLOW : • 'hydroxy' and 'methyl' reversed; • 2-cyanopropan-2-ol; • 2-methylpropan-2-olnitrile; • 2-cyano-2-hydroxypropane NOT a mixture of names with 'cyanhydrin' ALLOW CN ⁻ and names Examiner's Comments Many scored most of the marks in the first sub-parts. The name 'cyanohydrin' was accepted in (i) though many, to their credit, had a stab at the systematic name.
		ii	alkene / carbon to carbon double bond ✓ (primary) amide ✓	2	IGNORE 'C=C' 'secondary' is CON Examiner's Comments A few confused amides and amines.
		iii	methanol / CH ₃ OH ✓	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	addition (polymerisation) since C=C / carbon-carbon double bond / alkene double bond / unsaturated ✓ <pre> H H - C - H H H - C - C - H C=O O H - C - H H ✓ </pre>	2	both points needed to score first mark ALLOW 'CH₃' groups not displayed, but everything else must be full structural IGNORE brackets and 'n' Examiner's Comments This part caused more problems. Of the many who identified the type of polymerisation as addition, quite a proportion failed to state that it was the carbon-carbon double bonds that caused it. The structure was often erroneously connected through parts of the ester and some who got the structure correct failed to display the ester link.
	d	i	electrophilic substitution ✓	1	
		ii	C ₆ H ₅ OCl ✓	1	ALLOW atoms in any order
		iii	3 ✓	1	Examiner's Comments Was usually well-done. The commonest errors were to write C₆H₄OHC/ for the molecular formula and identify 5 isomers (forgetting the symmetry).
	e		 I—C/ polarised since electronegativity difference AW ✓ I / I⁺ / I^{δ+} is the electrophile / is attracted to delocalised electrons / is attracted to electron density ✓	3	ALLOW formula of any iodophenol but must be monosubstituted NOT hydrogens on the ring here 'addition' is CON Examiner's Comments Required thoughtful understanding of electrophilic substitution and was well done in many cases, with candidates showing one isomer of iodophenol, discussing the polarity of IC/ in terms of electronegativity and then saying that iodine acted as an electrophile.
			Total	24	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5	a	i	 backbone and ester groups displayed ✓ C₃H₇ groups displayed ✓	2	ester groups wrong way round scores zero Examiner's Comments Many candidates could draw the triester correctly, the main error being the careless omission of one or more hydrogen atoms.
		ii	No carbon-carbon double bonds / No C=C OR all C-C bonds are single ✓	1	Not just 'double bonds' for 'C=C' Examiner's Comments There were a lot of correct answers but the double bonds had to be described as between carbon atoms.
	b	i	 unpaired electron ✓	2	IGNORE 'lone', 'single', 'unbonded' Mark separately Examiner's Comments Most could draw a hydroxyl radical. The use of 'double half arrows' to indicate electron movement was less well known, however. Most could name 'homolytic fission'.
		ii		1	arrows must be 'half-arrows' and (when projected) start on bond and end on atoms Examiner's Comments Most could draw a hydroxyl radical. The use of 'double half arrows' to indicate electron movement was less well known, however. Most could name 'homolytic fission'.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	homolytic (fission) ✓	1	ALLOW homolysis Examiner's Comments Most could draw a hydroxyl radical. The use of 'double half arrows' to indicate electron movement was less well known, however. Most could name 'homolytic fission' and classify the types of radical reaction.
		iv	only 5.4 initiation ✓ rest propagation ✓	2	mark separately Examiner's Comments Most could draw a hydroxyl radical. The use of 'double half arrows' to indicate electron movement was less well known, however. Most could name 'homolytic fission' and classify the types of radical reaction.
		v	$\text{O}_2 + \text{R}-\text{CH}_2-\text{CH}_2\cdot \rightarrow \text{R}-\text{CH}(\text{OOH})-\text{CH}_2\cdot$ ✓	1	ALLOW $\text{R}-\text{C}(\text{OOH})\text{H}-\text{CH}_2\cdot$ but end bonds must be there Examiner's Comments Most could draw a hydroxyl radical. The use of 'double half arrows' to indicate electron movement was less well known, however. Most could name 'homolytic fission'. Many added the same extra molecule on each side and some got it right but left off one of the right-hand bonds, again a copying error.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		vi	aldehyde ✓ ((conc) sulfuric / hydrochloric) acid AND (potassium / sodium) dichromate AND heat / warm / reflux / distil AND green / blue ✓	2	ALLOW alkanal IGNORE carbonyl ALLOW formulae instead of names for second mark, but IGNORE incorrect formulae if correct names given IGNORE oxidation state of dichromate IGNORE 'orange' but any other starting colour is CON ALLOW: • 'silver nitrate and ammonia' / Tollens reagent and 'black ppt / silver' • Fehling's / Benedict's reagent and 'red ppt' • 'acid permanganate' (names or formulae) and 'colourless' no ecf from first mark and second mark depends on first being scored. Examiner's Comments Most could draw a hydroxyl radical. The use of 'double half arrows' to indicate electron movement was less well known, however. Most could name 'homolytic fission'. Might well have come as a welcome relief and most got it right.
			Total	12	
6			D	1	
			Total	1	
7			C	1	
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
8	<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.

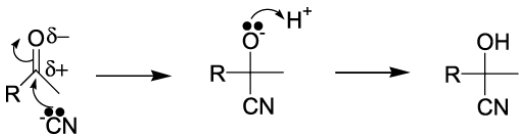
Mark Scheme

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
9	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

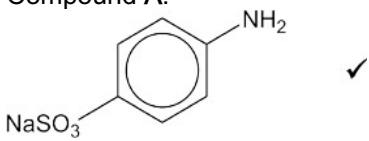
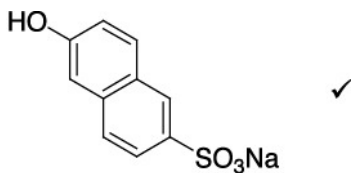
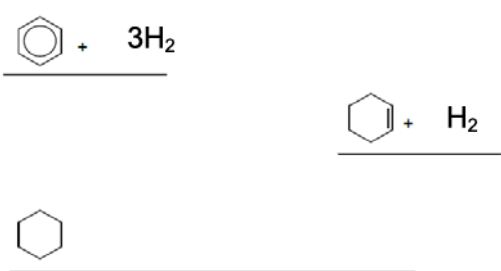
Mark Scheme

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
	c		 Arrow from negative charge on cyanide ✓ Partial charges on C=O correct AND arrow on carbonyl ✓ Intermediate correct ✓ Arrow from O to H AND correct cyanohydrin structure ✓	4	Arrows MUST BE double headed AND pointing towards correct atom ALLOW lone pair inserted on C and arrow starting from there
			Total	11	
10			A	1	
			Total	1	
11			D	1	
			Total	1	
12			A	1	
			Total	1	
13			B	1	
			Total	1	

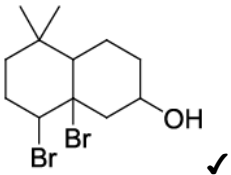
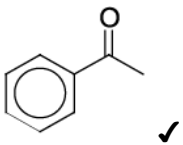
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14		i	1 electron from each carbon ✓ is delocalised (so all bonds are equal) ✓	2	
		ii	1. Electrons move to a higher energy level ✓ 2. Absorbing em radiation $\Delta E = h\nu$ ✓ 3. Yellow dye has more delocalisation / larger chromophore AND energy levels are closer together / ΔE is smaller ✓ 4. Energy absorbed is at lower visible frequencies ✓ 5. Complementary colour is transmitted ✓	5	ALLOW reverse: 3. Benzene has less delocalisation / smaller chromophore AND energy levels are further apart. 4. Energy absorbed is higher frequency (in the UV) 5. All visible colours transmitted
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a		Compound A:  First reaction: Reagents: HCl / H⁺ and NaNO₂ OR HNO₂ ✓ Condition: below ✓ 5 °C Second reaction: Reagents / conditions:  NaOH ✓	5	ALLOW names (including 'nitrite', 'nitrous acid') ALLOW -O⁻ for -OH ALLOW NaOH as reagent or condition IGNORE temperature for second reaction
	b		3H₂ on top left line and H₂ on top right line ✓ indication that left-hand side is less than 3 × right-hand side OR that gap between benzene and cyclohexene is less than three times value for cyclohexene ✓	2	
Total				7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16	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	
17	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
18	a	i	2,6-dichloro-3,5-diethylphenol	1	Ignore, commas, dashes and gaps
		ii	greater activity since longer alkyl groups OR less toxic (when taken by mouth) since more substitution	1	must have reason as well as effect to score
		iii	activity decreases since no halogen in 4 position ✓ less soluble since more substituted ✓	2	must have reason as well as effect to score two correct effects alone score 1 mark
	b		(aromatic compounds have) delocalised electrons that are lost on addition AND retained on substitution ✓ (loss of delocalisation causes) less stability AW ✓	2	
	c		-OH hydrogen bonds to N/N-H/O on protein	1	
	d		anion is more stable ✓ overlap of p-orbital on chlorine with delocalised / π electrons of ring ✓	2	Answers can be in either order Idea of negative charge of anion being spread over the delocalised system and Cl side group
	e		(water) hydrogen bonds ✓ (non-polar) instantaneous dipole-induced dipole ✓	2	must be spelled correctly, no abbreviations
	f		FIRST CHECK ANSWER ON ANSWER LINE IF pH = 6.19 award 3 marks conc of PCMX = $0.330/156.6$ OR 2.1073×10^{-3} (mol dm ⁻³) ✓ [H ⁺] = $\sqrt{(1.99 \times 10^{-10} \times 2.1073 \times 10^{-3})}$ OR 6.4757×10^{-7} (mol dm ⁻³) ✓ pH = 6.19 ✓	3	ALLOW ECF from each stage ALLOW 6.2 ALLOW 2 or more sf

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	g		<i>First please read point 10 of the instructions for marking 'Level of Response' mark-schemes on page 4</i> Level 3 (5–6 marks) Learners show comprehension of information from the article to produce a full response containing most of the scientific points. <i>The explanation is relevant and logically structured and contains no errors.</i> Level 2 (3–4 marks) Learners show some comprehension of information from the article to produce a partial response containing some of the scientific points <i>The explanation is generally relevant and logically structured and contains few errors.</i> Level 1 (1–2 marks) Learners show partial comprehension of information from the article to produce a response containing a few of the scientific points <i>A partial explanation is attempted and has some structure.</i> Level 0 (no marks) No response or no response worthy of credit.	6	Indicative scientific points may include Soap • Soap formed by reaction of ricinoleic acid with NaOH • ionic head • (largely) non-polar tail • structure (eg sodium ricinoleate) Solubility • PCMX low solubility in water because only the OH group can form hydrogen bonds • PCMX held in micelles / description of micelles (by soap molecules) ALLOW 'held in pine oil droplets that are made soluble(AW) by soap molecules' as an alternative held by id-id bonds in micelles • ionic heads allow solubility in water / forms hydrogen bonds with the water molecules • equilibrium with free PCMX in water • idea of reservoir
			Total	20	

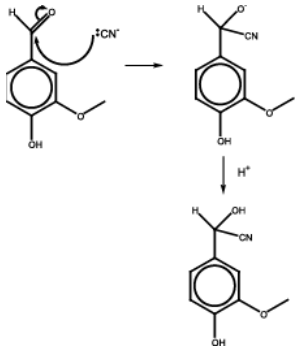
Mark Scheme

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.

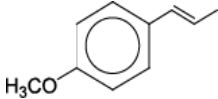
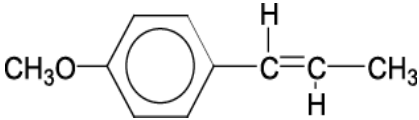
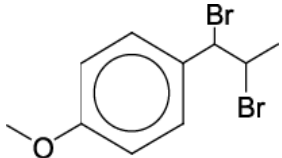
Mark Scheme

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.

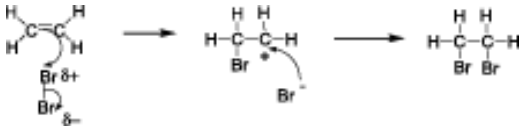
Mark Scheme

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 $\text{C}=\text{O}$ ($\delta^+ \text{C}=\text{O} \delta^-$) ✓ 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.

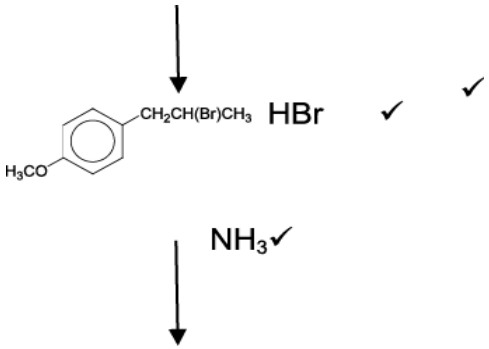
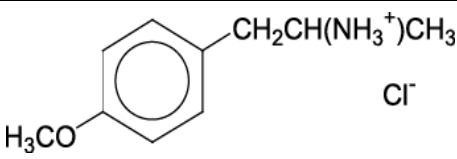
Mark Scheme

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^{delta+}✓ (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.

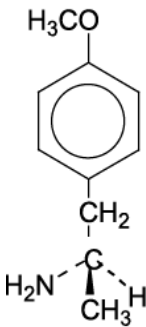
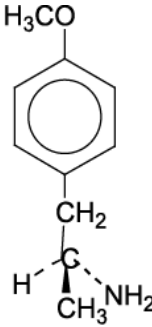
Mark Scheme

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	 Reaction scheme for question e(i): Anethole (1-methoxy-4-propylbenzene) reacts with HBr to form 1-bromo-1-(4-methoxyphenyl)propane, which then reacts with NH₃ to form the final product.	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	 Chemical structure of the product for question ii: 1-(4-methoxyphenyl)propan-1-aminium chloride.	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 <i>doesn't</i> 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.

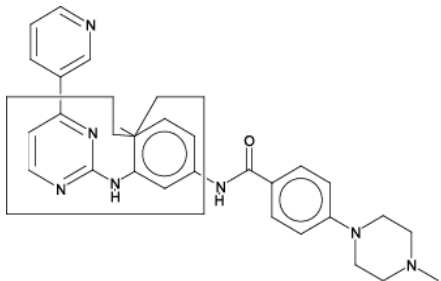
Mark Scheme

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	i	ester →; reaction with 3KOH and 3 salts formed ✓ propane-1,2,3-triol ✓	3	ALLOW any unambiguous structural formulae to score eg –OOCR etc for esters ALLOW with OH[–] as reactant and carboxylate ion as product, without K⁺ spectator ion ALLOW ‘OK’ but not ‘O–K’ for ‘O[–] K⁺’ Give one mark for ester and triol structures swapped as reactant and product Examiner's Comments Many candidates gave the correct formulae of the triester and the ‘glycerol’. Fewer gave the formula of the salt but many lost this mark for simply not putting ‘3’ before the ‘KOH’.
		ii		1	ALLOW ‘RC’ without bond Examiner's Comments This was high-scoring with most candidates giving the correct ester formula and displaying all the bonds.
		iii	methanol and conc sulfuric acid/ conc hydrochloric acid ✓	1	ALLOW formulae IGNORE carboxylic acid if mentioned Examiner's Comments Some candidates correctly gave ‘methanol and concentrated sulfuric acid’ but the ‘methanol’ was relatively rare.
	b		nitrogen/ argon other named noble gas ✓ high boiling point/ involatile/ non-volatile liquid ✓ some time unit ✓	3	ALLOW formulae Examiner's Comments Most gave a suitable inert gas and many mentioned ‘high-boiling liquid’. Some gave a unit of time but this was a place where ‘read the question’ was paramount with the majority not appearing to notice the word ‘units’.
			Total	8	

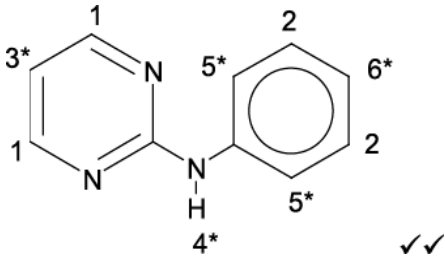
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22	a		the N atoms hydrogen bond (to water)	1	Examiner's Comments Most realised that hydrogen bonding was the key but not all mentioned the nitrogen atoms in this context.
	b	i		1	ALLOW lines cutting bonds to do so anywhere on the bond. Examiner's Comments Many circled the correct structure, omitting the methyl group, which was impressive. Including the methyl group was the common error.
		ii	<i>shape</i>: it has correct shape/ similar shape to substrate/ complementary shape to the enzyme/active site ✓ <i>binds</i>: to fit into/binds/bonds with active site ✓ <i>blocking</i>: blocking it to <u>substrate</u>/competing with <u>substrate</u> AW → C: C fits into one/fewer enzyme(s) OR resembles the substrate more/ fits/binds better OR forms more/stronger imb AW ✓	4	QWC: word 'substrate' must be used and spelled correctly to score third marking point. This must be comparative can score first mark here Examiner's Comments There were some good, well expressed, answers here. Many stated that the pharmacophore had the same shape as the substrate and thus fitted into the active site of the enzyme, competing with the substrate. C fitted better which made it more specific. Some omitted reference to shape or said that the shape was complementary to the substrate or the same as the active site. Many wrote that C had an extra methyl group without further detail.

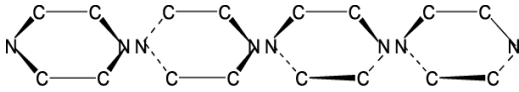
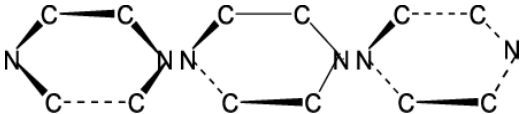
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	conc nitric and sulfuric acids ✓ (below) 55 °C ✓	2	ALLOW formulae. 'Conc'/'concentrated'/'c.' must be mentioned once somewhere 'reflux' is CON Mark separately Examiner's Comments Most gave concentrated nitric and sulfuric acids and below 55°C. The commonest error was to omit the 'conc'.
		ii	tin and concentrated/conc hydrochloric acid	1	IGNORE formulae IGNORE 'hydrogen chloride' Examiner's Comments This was another 'read the question' moment. The question asked for 'names' but many gave formulae. The question was asking candidates to interpret the formulae on the Data Sheet.
		iii	(secondary) amide ✓ C ₆ H ₅ COCl ✓ benzoyl chloride ✓	3	ALLOW C₆H₅CO-O-COC₆H₅ ALLOW molecular formulae and any type of structural formula ecf: Name can match formula but only for benzoic anhydride or benzoic acid. Examiner's Comments Most knew 'amide' and many thought erroneously that the reagent was benzoic acid. 'Error carried forward' was available for the name, but many got it wrong. The correct reagent was benzoyl chloride and few got this and even fewer got both name and formula.
	d	i	C ₁₀ H ₉ N ₃	1	ALLOW elements in any order Examiner's Comments Most got this correct (C₁₀H₉N₃).

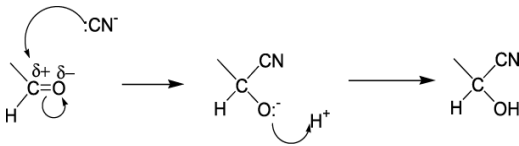
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii		2	Asterisked numbers can be transposed two marks for completely correct; <i>one mark if:</i> '5' and '5' shown as the same (NOT 1) and different from others on right-hand ring and '4' shown as an unique no. OR all correct except for the omission of a number on the NH ALLOW '4' above N Examiner's Comments A few candidates correctly worked out that there were six peaks and labelled the structure correctly. Those who thought that there were three equivalent protons on each ring were often able to gain partial credit through the mark-scheme.

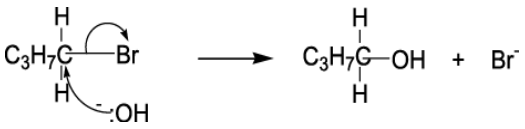
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e		109 (⁰) ✓ pyramidal ✓ 4 groups/pairs of electrons/ 4 areas of electron density ✓ (electrons) repel and get as far away from each other as possible ✓ diagram of either chair or boat or 3D structure (wedges and dashes) ✓ eg award the mark to: 	5	ALLOW 105 – 110 IGNORE 'trigonal', 'triangular' and 'tetrahedral' no ecf from angle on 3rd mark. QWC Do not award third mark if angle incorrect ALLOW 'minimise repulsion' IGNORE 'repel as much as possible' Examples shown are not exhaustive. Four adjacent atoms connected by the same three symbols is incorrect (no mark) eg:  IGNORE CH₃ groups on nitrogen or hydrogens or lone pairs or bond angles Examiner's Comments This was well answered though most got the correct angle of 109° caused by four areas of electron density, fewer realised that the shape around the nitrogen atoms was pyramidal, not tetrahedral. The diagram clearly took candidates out of their comfort zone but many who attempted it got an acceptable structure.
	f		Each atom in the ring contributes one electron ✓ electrons delocalised ✓ two rings of electrons above and below ring (of atoms)/ plane/atoms/ molecule ✓	3	ALLOW N atoms contribute two/lone pair electrons must make it clear there are two rings Examiner's Comments Most realised that they were basically describing benzene. Almost all said 'delocalised' and many said 'two rings above and below the plane of the C-N ring'. There were again problems of communication, for example 'a ring, above and below...'. Some realised that each C and N atom contributed one electron.
			Total	23	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23	a		blue (solution) ✓ red/orange ppt ✓ Cu ₂ O ✓	3	ALLOW these colours or any combination but no others. ALLOW copper(I) oxide
	b	i	 attack on aldehyde showing curly arrows and partial charges ✓ intermediate (with negative charge) and attack by H⁺ (including curly arrow) ✓ product ✓	3	Curly arrows must start (when projected) on a bond (or lone pair or minus sign) and end (when projected) on an atom ALLOW rest of acrolein structure or 'R' on 'spare' bond(
		ii	HCN/CN ⁻ is nucleophile ✓ will not attack negative charge of C=C/no positive/δ ⁺ for nucleophile to attack ✓	2	IGNORE reference to electrophiles.
			Total	8	

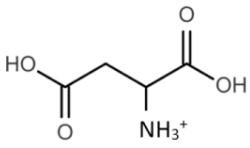
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
24	<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) Detailed deductions about the mechanisms, orders of reaction and rate of both equations 3.2 and 3.3. <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) Outline comments about the mechanisms, orders of reaction and rate of both equations 3.2 and 3.3 but some detail excluded. OR Detailed deductions about the mechanism, order of reaction and rate of either equation 3.2 or 3.3. <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 comments about the mechanisms, orders of reaction and rate of both equations 3.2 and 3.3, no detail. OR Outline comments about the mechanism, order of reaction and rate of either equation 3.2 or 3.3. <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 include: Mechanism Equation 3.2 - second step is $(\text{CH}_3)_3\text{C}^+ + \text{OH}^- \rightarrow (\text{CH}_3)_3\text{COH}$ - this is fast (not rate-determining) Equation 3.3 - occurs in a step in which Br^- leaves as OH^- enters AW - since only one step Orders of reaction Equation 3.2 - first order with respect to $[\text{RBr}]$ RBr occurs in rds - zero order with respect to $[\text{OH}^-]$ $[\text{OH}^-]$ occurs in fast step (only) Equation 3.3 - both RBr and OH^- are first order RBr and OH^- both appear once in the single step Rate equations Equation 3.2 – Rate = $k [\text{RBr}]$ Equation 3.3 – Rate = $k [\text{RBr}][\text{OH}^-]$ Mechanism 
	Total	6	

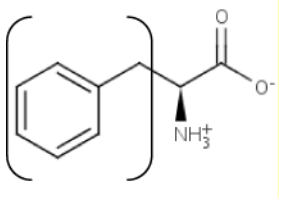
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25			B	1	
			Total	1	
26			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a		To allow the liquid to boil more gently / AW✓	1	ALLOW no sudden boiling / controls boiling / stops it boiling over / reduce the bubbling IGNORE references which imply catalytic activity IGNORE references to air IGNORE 'spitting' Examiner's Comments This practical technique question was generally well answered.
	b	i	1 carboxylic acid 2(secondary) amide 3 ester $\left. \begin{array}{l} \\ \\ \end{array} \right\}$ all three needed ✓	1	DO NOT ALLOW polyamide or polyester or amine IGNORE references to peptide link Spelling must be correct for ester Examiner's Comments A fairly straightforward question requiring the identification of functional groups. Common incorrect responses included polyamide/peptide or amine and ether.
		ii	 ✓ NH₃⁺ ✓ rest of molecule	2	ALLOW full and condensed (eg COOH) formulae ALLOW ambiguous attachment to NH ALLOW charge on H or N IGNORE spurious bond attachment e.g. to H atom Don't forget second mark for 'rest of structure' Examiner's Comments Many candidates scored the ion (NH₃⁺) mark but a minority did not correctly work out the rest of the structure.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	 'Structure' of zwitterion ✓ Zwitterion formed from internal acid / base reaction ✓	2	ALLOW COO^- or CO_2^- IGNORE ambiguous attachments from ring (see brackets) ALLOW answer in terms of proton transfer e.g. NH_2 gains proton / H^+, OH loses proton Examiner's Comments In this question the majority of candidates produce a correct zwitterion structure but unfortunately their explanation of the internal proton transfer lacked detail or sloppy terminology (e.g. hydrogen instead of hydrogen ion or proton).

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	c	<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) Full treatment using majority of ‘set-up’ points AND both expected observations and interpretation <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) Most of key ‘set-up’ points described AND expected observations OR interpretation <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) A limited treatment using some of set-up points OR expected observations OR interpretation <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 <i>No response or no response worthy of credit.</i>	6	indicative scientific points may include: NB: A labelled diagram may illustrate some of set-up points and / or observations. Develop practical techniques and procedures <i>set-up</i> • samples of solutions of hydrolysis mixture, pure amino acids / salts and aspartame • water / solvent in beaker • <u>pencil</u> line on chromatography paper • above level of water / solvent in beaker • samples spotted onto line, evenly spread • paper supported in beaker with lid / film • remove when solvent near top • locating agent used (ninhydrin / iodine/UV source) <i>expected observations</i> • two spots from hydrolysed sample ALLOW three spots (aspartame) • one spot at different heights for each pure aa ALLOW observations on a diagram <i>interpretation</i> • (two spots from hydrolysed sample show) <u>two aas present</u> • level with samples OR compare R_f values show the two suspected aas present. Examiner’s Comments Many candidates produced well-structured answers to this practical technique question. The explanation of how their results could be used to show hydrolysis had taken place tended to be the weaker part of some answers.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		(phosphoric) acid <u>catalyst</u> for hydrolysis (of aspartame)✓ Lower concentration / amount in regular therefore reaction (hydrolysis) <u>slower</u> ✓ ORA	2	IGNORE answers linked to le Chatelier using <i>acid as reactant rather than catalyst</i> DO NOT ALLOW 'gets hydrolysed less' Examiner's Comments Very few students realised the phosphoric acid acted as a catalyst in the hydrolysis of the aspartame. A minority thought that there would be less hydrolysis overall, not <u>slower</u> hydrolysis.
			Total	14	
28			B	1	
			Total	1	

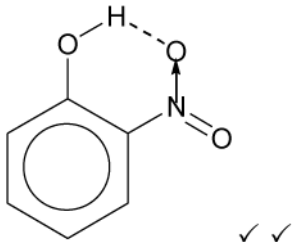
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a		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.
	b		use equal vols / same amount of ocimenol and cinnamyl alcohol ✓ add bromine dropwise / from a burette ✓ bromine decolourised ✓ more drops / volume/greatest titre decolorised for ocimenol / more unsaturated molecule ✓	4	ORA on first two marks ALLOW answer can be in terms of colorimetry and absorption of final solution ALLOW answers in terms of add bromine solution until first permanent brown / yellow IGNORE references to time / rate of decolourisation Examiner's Comments This question was variably answered. Examiners were looking for the simple idea that equal volumes / amounts of the two alcohols could have bromine solution added (either dropwise or by titration) until an orange colour persisted. A significant number of candidates wrongly thought time was a factor and many candidates tried to use a colorimetric method. This is fine, but required a more sophisticated answer to score all four marks.

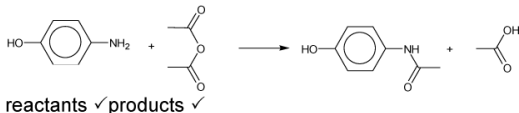
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	8	

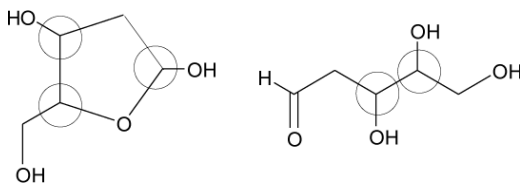
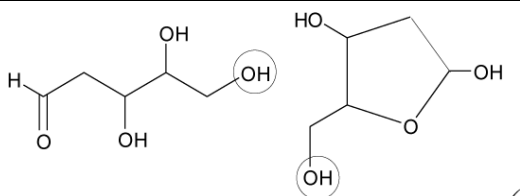
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30	a		Phenol / hydroxy(l) ✓ <u>secondary</u> amide ✓	2	NOT alcohol Examiner's Comment: A very straightforward question, well answered by many candidates. Common errors included identifying the OH group as an alcohol rather than phenol, or failing to indicate that the amide group was a secondary amide.
	b	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 NO ₂ 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 NO ₂ 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 NO ₂ 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 NO ₂ functional group into a NH ₂ functional group is an example of a reduction reaction and so failed to score this mark.

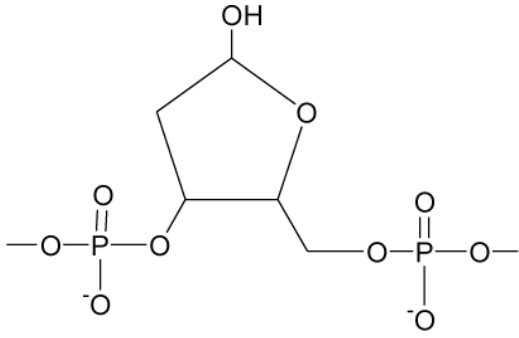
Mark Scheme

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	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
31	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.										

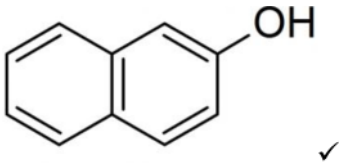
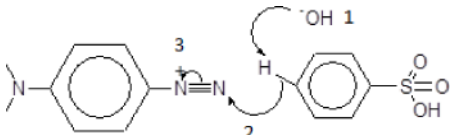
Mark Scheme

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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32	a	i	<i>Bond angles:</i> Both have bond angle of 120° ✓ Both structures have three areas of electron density/ 3 groups (or regions or sets) of electrons/ 3 areas of <u>negative</u> charge (repelling) ✓ <i>Bond lengths:</i> Structure 1, all bond lengths the same. ✓ Structure 2, C=C shorter than C-C ✓	4	marks for bond angle and explanation. 2nd mark depends on the first 1 mark for bond lengths in each structure. Examiner Comments The different bond lengths were well explained, although some candidates said there were shorter and longer bonds in structure 2, but did not say the double bonds would be the shorter ones. The bond angles were more difficult; angles of 60° were quite common, as were 109° in structure 2. Even if both were given as 120°, the explanation in terms of areas of electron density was rarely seen.
		ii	Structure 2 would be expected to have ΔH of 3 x cyclohexene/ $(-360 \text{ (kJmol}^{-1}\text{)})$, ✓ benzene/structure 1 has delocalised (electrons) ✓	2	Examiner Comments This was well done, although some candidates did not use the word 'delocalised' to explain the less exothermic enthalpy value for structure 1.
	b	i	(Temp) below 55°C OR 55°C ✓ $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^{+} + 2\text{HSO}_4^{-} + \text{H}_3\text{O}^{+}$ ✓	2	IGNORE any reagents mentioned or conditions other than temperature for the first point ALLOW $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{NO}_2^{+} + \text{HSO}_4^{-} + \text{H}_2$ ALLOW $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{NO}_3^{+} + \text{HSO}_4^{-}$ then $\text{H}_2\text{NO}_3 \rightarrow \text{NO}_2^{+} + \text{H}_2$ Examiner Comments The majority of candidates had the correct temperature, although some had refluxing as well or confused the conditions and put less than 5°C. The equation for the formation of the electrophile proved more difficult for many.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	NaNO₂/ Sodium nitrate(III)/ sodium nitrite AND HCl ✓ Temp below 5°C ✓  Alkaline conditions AW ✓	4	ALLOW HNO₂/name ALLOW ice cold ALLOW H drawn on coupling carbon ALLOW third mark if appropriate conditions shown in middle box IGNORE any other reagents in bottom box unless CON Examiner Comments There was some confusion with sodium nitrate and sodium nitrite here and not realising the coupling with the phenol had to be done in alkaline conditions. The structure was, however, well answered.
	c		(Sodium) Sulfonate	1	IGNORE any oxidation state given Examiner Comments Naming the sulfonate group proved difficult for most candidates.
	d		✓ ✓ ✓ 1 for each arrow 	3	ALLOW arrows that, if continued in the same direction, would start and finish in the correct places, (anywhere on appropriate atom or bond). ALLOW arrow from H into the ring AND an arrow from the ring to the right-hand N as alternative for arrow 2 Examiner Comments There were a significant number of candidates who overlooked this question. Of those who did it, points 1 and 3 were the easiest to see where electrons were moving to and from.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e		FIRST CHECK ANSWER ON ANSWER LINE If answer = 0.8(0) award 2 marks $[H^+] = 10^{-3.7}$ evaluated = 2.0×10^{-4} ✓ $K_a/[H^+] = [In^-]/[HIn]$ evaluated = 0.80 ✓	2	Must have 'H⁺ =' to score the first point ALLOW 1: 1.25, 4: 5 etc NOT 1: 0.8 Examiner Comments This question was well done, although the ratio was the wrong way round in some cases. If full marks were not scored then the clarity of the working out was an important factor. If the pH had been used to find $[H^+]$, it needed to be clearly stated to score.
			Total	18	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33		i	<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) Shows a good understanding of all three areas <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) Shows a sound understanding of at least two areas. OR Discusses all three areas, demonstrating a sound understanding of one area <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) Shows some understanding of one area. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 (0 marks) <i>No response or response has no merit.</i>	6	Indicative scientific points include Why radiation absorbed • electrons move to higher energy levels / shells • absorbing light / radiation • frequency absorbed $\Delta E = h\nu$ (allow $E = h\nu$ if clear reference to energy gap) Affect of structure on frequency of radiation • amount of délocalisation affects ΔE / frequency • smaller delocalisation, larger ΔE / frequency • lignin has smaller chromophore / less delocalisation than decomposition prods Source of yellow colour • uv higher frequency / larger ΔE than visible • look yellow because they absorb the complementary colour / blue / violet For answers that talk about electrons falling and releasing radiation / light / colour impedes the line of reasoning and should result in the lower mark within a level being awarded. Examiner's Comment: This question produced a full range of marks and allowed the more able candidates to demonstrate their understanding of this topic. Most candidates were able to explain what happens to electrons when they absorb radiation and linked this to the idea of quantisation of energy. They also linked the amount of energy to the appropriate frequency absorbed and that this could be used to identify the colour of the decomposition products as being complimentary to the frequency / colour

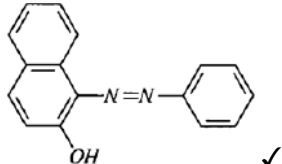
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					absorbed. More able candidates also discussed the nature of the chromophores in lignin and in its decomposition products and correctly stated that when the degree of delocalisation in the chromophore increased, this reduced the size of the energy gap between the ground state and the excited state and that this resulted in the decomposition products absorbing light in the blue(or violet) part of the visible spectrum and so the complimentary colour was reflected. Some candidates did lose marks for stating that the colour produced was a result of electrons being promoted to a higher energy level and then dropping back to their ground state with the release of energy in the visible spectrum that resulted in the paper appearing yellow. This question gave very clear differentiation between the candidates, strong candidates produced a very clear and well organised response that addressed all three areas in depth. Whereas, weaker candidate responses were characterised by a lack of organisation, or in producing a response that either only addressed one area, or gave a brief account of what happens when radiation is absorbed by molecules and how this produced a yellow colour.
		ii	FIRST CHECK ANSWER LINE <i>If answer = 342 (kJ mol⁻¹) award 3 marks</i> Rearrangement of $E = h\nu$ and $c = \nu\lambda$ to $E = hc/\lambda$ ✓ $E = 6.63 \times 10^{-34} \times 3 \times 10^8 / 3.5 \times 10^{-7}$ (J per atom) OR $E = 6.63 \times 10^{-34} \times 8.57 \times 10^{14}$ ✓ multiply by N_A and divide by 1000 and evaluate $(6.63 \times 10^{-34} \times 3 \times 10^8 \times 6.02 \times 10^{23} / 3.5 \times 10^{-7} \times 1000) = 342 \text{ kJ mol}^{-1}$ ✓	3	ALLOW ecf MP2 subsumes MP1 and scores 2 marks Examiner's Comment: This question was generally well answered with many candidates scoring at least 2 marks for the correct rearrangement of $E = h\nu$ and $c = \nu\lambda$, and then the correct calculation of the energy of the photon absorbed. More able candidates subsequently calculated the energy per mole correctly as 342kJ mol⁻¹.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
34			B	1	<u>Examiner's Comments</u> C was the most frequently seen answer as candidates did not use 2 as the molecular mass of hydrogen in calculating moles
			Total	1	
35			A	1	<u>Examiner's Comments</u> More than half the candidates scored this mark. Option B, the tertiary alcohol, was the most frequently seen incorrect answer.
			Total	1	
36			D	1	
			Total	1	
37			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38	a		(conc) Hydrochloric acid / sulphuric and sodium nitrate(III)/nitrite ✓ Phenylamine / aminobenzene ✓ Below 5°C/ice cold (solution) ✓	3	ALLOW nitrous acid for first mark name or formula IGNORE nitric acid If acid named with oxidation state it must have correct oxidation state i.e. III ALLOW hydrochloric acid under 'Conditions' for <u>first</u> mark Alkaline conditions CON <u>Examiner's Comments</u> There were many good responses but the identity of phenylamine as one of the reagents was often missed, candidates perhaps not noticing the question asked for the reagents needed to make the particular compound shown in the stem.
	b	i		1	ALLOW 
		ii	alternating double and single bonds OR conjugated system OR delocalisation of <u>electrons</u> ✓ split into different electronic energy levels OR electron(s) promoted OR excited from lower to higher level OR electron(s) excited to a higher energy level ✓ can absorb <u>visible/coloured</u> light (causing electrons to be promoted to upper level) ✓ reflected/transmitted light complimentary colour ✓	4	The idea of split (electronic) energy levels needed for this mark (energy gap on <u>own</u> not good enough) NOT energy states Emit colour/light is CON ALLOW opposite colour <u>Examiner's Comments</u> This question was generally well answered, but some candidates treated the process as emission spectra (e.g. 'when the electrons drop back in energy level the emitted light is the complimentary colour.'

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Colour	1	ALLOW the chromophore. IGNORE any reference to specific colour. For (c)(i) and (c)(ii) must talk about a dye property IGNORE references to bonding possibilities <u>Examiner's Comments</u> Common incorrect answers included solubility (the answer to 1cii), and colourfastness.
		ii	Solubility OR <u>more</u> soluble	1	LESS soluble is a CON <u>Examiner's Comments</u> Some candidates talked about the nature of bonding to the fibre rather than a property of the dye.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
39		i	Any three from: enthalpy change of hydrogenation of benzene is less (exothermic) than $3 \times$ enthalpy change of hydrogenation of cyclohexene ✓ (therefore) bonding in benzene is not 3 (C=C) double bonds (and 3 C—C bonds) / benzene does not have alternating single and double bonds between the carbon atoms ✓ benzene is more stable ✓ benzene has delocalised electrons / structure ✓	3	ALLOW points made on a diagram ALLOW any appropriate comment relating to delocalisation in benzene <u>Examiner's Comments</u> This question showed a full range of marks, with most candidates making an attempt to answer it as fully as possible. Many candidates scored two marks for correctly stating that the structure of benzene was more stable than expected (if it were the Kekulé structure) due to the presence of the delocalised ring. However, a number of candidates lost marks for claiming that cyclohexene contained three double bonds and then tried to justify their answers from this premise. A significant number of candidates had recalled the value for the hydrogenation enthalpy of cyclohexene (-120kJ/mol) and then tried to use this in the context of their answers. Although they calculated that benzene should be three times the value quoted, (-360kJ/mol), they did not make it clear that the reaction for benzene was less exothermic, and often stated that it was more exothermic which negated marking point 1 on the mark scheme.

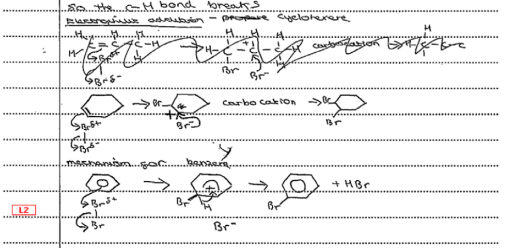
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	<i>Refer to marking instructions on page 6 of mark scheme for guidance on marking this question.</i> Level 3 (5–6 marks) A detailed comparison that identifies products and reaction conditions for both reactions. AND Correctly identifies both reaction types. <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) Partial comparison of both reactions. AND Correctly identifies both reaction types. OR Detailed explanation of the one reaction. AND Correctly identifies ONE reaction type. <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) Partial comparison of both reactions. AND Attempts to identify the reaction types. OR Discusses both reaction types. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 <i>No response or no response worthy of credit.</i>	6	Indicative scientific points include: AO2.1 application of knowledge and understanding of cyclohexene reaction • product 1,2 dibromohexane • formula; • Br₂ decolourises • at room temp AO2.1 application of knowledge and understanding of benzene reaction • product bromobenzene • formula; • HBr as a product • needs reflux • halogen carrier • Fe/FeBr₃ catalyst May be given by use of appropriate equation(s) AO3.2 Conclusions about reaction types cyclohexene: • Electrophilic • addition <i>benzene:</i> • electrophilic • substitution; • maintains delocalisation <u>Examiner's Comments</u> This was the first of the two Level of Response questions on this paper. Many candidates struggled to score more than 4 marks on this question, with lower ability candidates often achieving Level 1 and a maximum of 2 marks. The most common issues in this question were the fact that candidates did not identify that the focus of the question was on the nature of the reactions rather than on the mechanism of the reactions. Consequently there were a lot of responses that gave detailed accounts on the general mechanisms of

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					electrophilic addition in alkenes, or electrophilic substitution in arenes without giving reference to the specific reaction conditions or products. Where candidates did address the reactions in the question they often did not state the type of reaction correctly, or identified the reaction incorrectly (e.g. as being nucleophilic rather than electrophilic). The only other common omission in candidates' responses was failing to name the products of the reactions either within the text, or by use of appropriate equations/formulae which would have been perfectly acceptable methods. Exemplar 3 <i>*Benzene contains delocalised electrons which make it a very stable molecule. This means it undergoes only electrophilic substitution reactions so that delocalised electrons & structure aren't disrupted. Benzene if heated under reflux with a catalyst (FeBr₃) undergoes a substitution reaction in which bromobenzene & HBr are formed. In this way delocalised electrons do not react. Cyclohexene has it has only one C=C reacts with Br₂ with an electrophilic addition (at room temperature) in which the C=C breaks down so that 1,2-dibromocyclohexane can be formed; this happens because cyclohexene does not have delocalised electrons & Br₂ reacts only where the C=C bond is present.</i> A clear succinct response, which addresses the Level 3 descriptor fully, scoring 6 marks.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 4 Exemplar 4 response scoring 4 marks, as both reaction types have been identified and products given via equations. To progress to L3 the candidate would have needed to include the reactants and reaction conditions for both reactions 2.e.ii  12

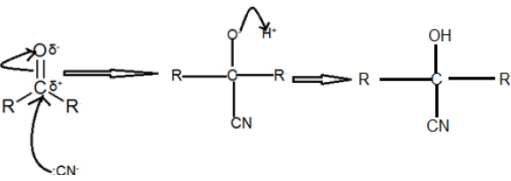
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 5 Cyclohexene undergoes electrophilic addition, whereas benzene undergoes electrophilic substitution. With cyclohexene, bromine molecules gain ~~an intermediate~~ a dipole as electrons in the bond repel from those in the C=C double bond. The slightly positive bromine then accepts electrons from the C=C bond, leaving a negative bromine to donate electrons forming another bond. In benzene, a bromine nucleophile is produced instead, as a positive bromide ion. This accepts electrons from the delocalised ring in benzene, replacing a hydrogen which donates electrons to the ring and leaves as an H⁺ ion. The reason for different reactions is that the delocalised electron rings of benzene give it high stability, whereas the single double bond of cyclohexene means it's not as stable. Therefore, more energy is required to break the delocalised ring of benzene in order to add groups, therefore it's less likely to occur so substitution happens instead. L1 response scoring 2 marks. The candidate identifies both reaction types but gives an explanation only in terms of mechanism involved. Does not address any of the criteria in AO2.1 for either reaction so cannot progress beyond Level 1
			Total	9	

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.

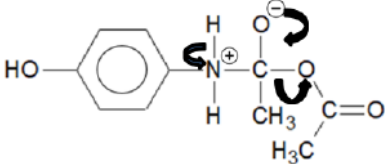
Mark Scheme

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) Examiner's Comments 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.
			Total	7	
41			Oxidation	1	ALLOW redox Examiner's Comments Very few candidates scored this mark. Some of the more common reactions suggested included hydrolysis, condensation, hydration and reduction.
			Total	1	
42			A	1 AO 1.1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
43		i	Aldehyde ✓	1 AO 1.1	IGNORE 'carbonyl'
		ii	$(-)\text{CHO} + \text{HCN} \rightarrow (-)\text{CH}(\text{OH})(\text{CN})$ ✓	1 AO 2.5	ALLOW any unambiguous structure <u>Examiner's Comments</u> Having identified the functional group in the previous part of this question, this 1 mark question required an equation to show how the aldehyde functional group reacts with HCN. —CHO or RCHO would have been sufficient to represent the aldehyde. Some candidates gave the whole mechanism with the aldehyde mentioned in (f)(i), which was not necessary. The best answers drew a semi-displayed product, as RCHOHCN was not clear enough without brackets, e.g. RCH(OH)(CN).
			Total	2	

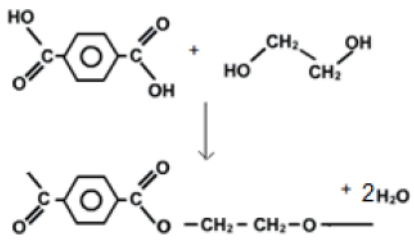
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
44	a		electrophilic substitution ✓ reduction ✓	2(AO 2.3 x2)	ALLOW nitration
	b		Keep away from flames ✓ AW Use in fume cupboard/well ventilated lab ✓ Wear (protective) gloves ✓	3(AO 3.2 x3)	Allow (lit) Bunsen burners/sparks IGNORE goggles <u>Examiner's Comments</u> Most candidates showed a good knowledge of appropriate safety precautions, although the suggestion of using a 'gas mask', as suggested by a small but significant proportion of candidates, was a disproportionate precaution relative to the hazard presented by ethanoic anhydride.
	c		 ✓	1(AO 2.5)	Curly arrows must start at any point on the correct bond or negative charge and point to the correct atom or bond. <u>Examiner's Comments</u> This question proved very challenging and only higher ability candidates were able to show the electron movements.  AFL It may help in future teaching and learning practice if students are encouraged to work backwards in questions like this. For example, in the paracetamol molecule the C=O must mean a pair of electrons have moved to form the 'second' bond in this structure. Likewise the three bonds to the N atom in paracetamol from the four bonds in the intermediate must mean the two bonding electrons have moved to the top H atom in the intermediate.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
45			D	1 (AO1.2)	
			Total	1	
46			C	1 (AO1.2)	
			Total	1	
47			B	1 (AO1.1)	
			Total	1	
48			D	1 (AO1.2)	
			Total	1	

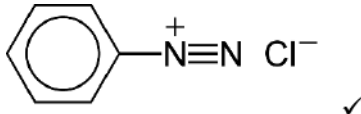
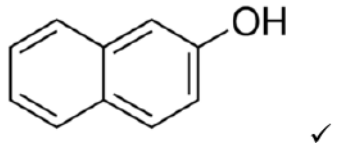
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
49	a	i	1,2-dichloroethane ✓	1 (AO1.1)	IGNORE dashes, commas and a gap between 'dichloro' and 'ethane'
		ii	Nucleophilic substitution ✓	1 (AO2.1)	
		iii	 Product (1 repeat unit)✓ Equation fully correct inc water ✓	2 (AO1.2 × 2)	ALLOW monomers either ways round and single bonded oxygen on either end. IGNORE bracket around repeat unit.

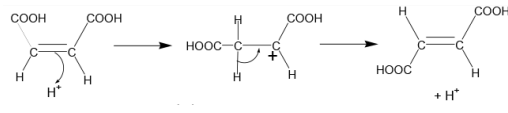
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		<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	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
50	a		Below 5 °C ✓  	1 (AO1.2 × 3)	Mention of alkaline conditions is CON ALLOW without chloride ion Bonding in naphthol must be as shown.
	b	i	Concentrated sulfuric acid and reflux OR fuming sulfuric acid and 40 °C ✓	1 (AO1.2)	ALLOW 'c'/'conc' for concentrated and formula
		ii	Dye C: Not very soluble as only the phenol group (and N atoms) can form H bonds <u>with water</u>. ✓ The rest of the molecule has weak id-id imbs. ✓ Dye D: More soluble because SO₃⁻/O⁻ can form ion dipole bonds <u>with water</u>. ✓ Forms more H bonds with water. ✓	4 (AO2.7 × 4)	Must mention groups that can H bond to score
	c	i	Electrons in the extended delocalised system ✓ electrons move to higher energy levels ✓ ΔE = hν ✓	3 (AO1.1 × 3)	Splitting d-orbitals is CON for MP1, IGNORE chromophore alone
		ii	Complementary colour is seen / frequencies not absorbed are seen (AW)	1 (AO1.1)	Light emitted is CON
	d		The <u>NH₂</u> groups on wool become <u>protonated</u>/turn to <u>NH₃⁺</u> in weak acid ✓ Ionic interactions between SO₃⁻/O⁻ groups and NH₃⁺ ✓	2 (AO2.7 × 2)	
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
51		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 ² H / 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.
			Total	5	
52		i	unsaturated...C=C / CC double bonds ✓ cis adjacent parts of chain next to each other around double bond (AW) ✓	2 (AO1.1×2)	i.e. avoids giving mark for C=O ALLOW π bonds in chains NOT just double bonds ALLOW H's / groups on same side / AW NOT in same 'plane'
		ii	instantaneous dipole – induced dipole between (non-polar) chains ✓ permanent dipole-permanent dipole between C=O / C–O bonds (AW) ✓	2 (AO2.1×2)	ALLOW both types of bond with inadequate locations for 1 mark NOT id-id? NOT pd-pd, unless correct term has to be used once; then allow pd
		iii	(Chains in) Structure A pack better / closer together / more;points of contact ✓ Stronger imb / id-id ✓ More energy / higher temperature required to break bonds ✓	3 (AO2.5×3)	ORA throughout. AW close enough No need to specify but for example H bonding would be a CON. ALLOW id-id. NOT fewer bonds
			Total	7	