

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

POLYMERS AND LIFE (PL)

SCORE

/595

PERCENTAGE

%

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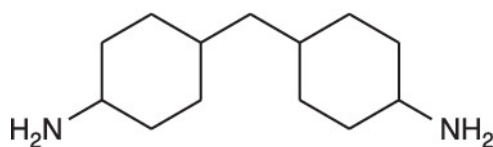
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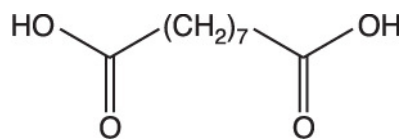
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- 1 Silk is a natural protein fibre. Early attempts to make a substitute 'silk' included the use of a polyester and a polymer called Qiana.

Qiana is made from two monomers, compound A and azelaic acid. Their structures are shown below.



compound A



azelaic acid

Qiana is a condensation polymer.

- (i) Underline **two** words from the list below which best describe a condensation reaction.

addition

elimination

neutralisation

rearrangement

redox

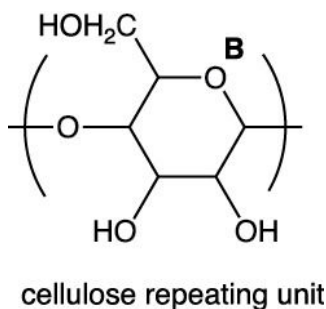
substitution

[1]

- (ii) Draw the structure of the linkage formed when a molecule of compound A and a molecule of azelaic acid react together.

[1]

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



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

----- [1]

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

[1]

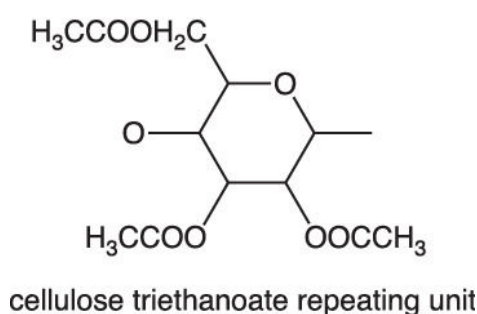
- (iii) Cellulose is made by condensation reactions of a single monomer.

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

[2]

- (b) Some data about the polymers used as a film base are summarised in the table given below. All of the polymers are transparent and flexible at room temperature.

Name	Approximate year introduced	Action when heated	Stability to decomposition at room temperature	Tensile strength
Cellulose nitrate	1889	extremely flammable	can break down explosively	medium
Cellulose triethanoate	1923	melts, does not burn	breaks down in warm humid conditions giving off choking vapours	medium
Polyester	1970s	melts, does not burn	stable	high



- (i) Give the systematic name for the 'choking vapours' given off when cellulose triethanoate is hydrolysed.

-----[1]

- (ii) Name all the types of intermolecular bonds between polymer chains in cellulose triethanoate and those in polyester polymers.

cellulose triethanoate -----

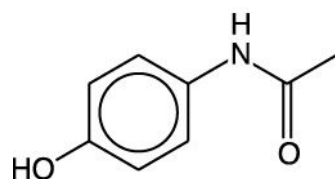
polyesters -----

-----[2]

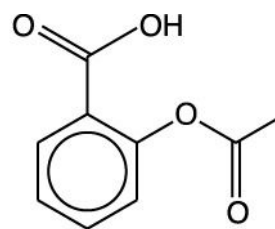
- (iii) All polyesters have the same linkage.

Explain what causes different polymers with the same linkage to have different strengths.

- 3 Disprin Extra is a medicine containing the active compounds C and D.



compound C



compound D

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

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



[2]

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

4(a) The structure of DNA is now well-established after Watson and Crick's work in 1953.

In this question refer to the *Data Sheet* for any necessary formulae.

(i) Give the name used to describe a repeating unit in a DNA chain.

-----[1]

(ii) DNA consists of a deoxyribose and phosphate backbone to which four bases are bonded.

Draw the structural formulae of the **two** products formed when one molecule of deoxyribose reacts with a phosphate ion.

[3]

- (b) In a scientific paper in 1953 Watson and Crick wrote 'It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material'.

Explain:

- how the adenine-thymine and guanine-cytosine base pairs are held together, stating the difference between the two different pairs
- how the specific pairing 'suggests a copying mechanism' for the replication of DNA.



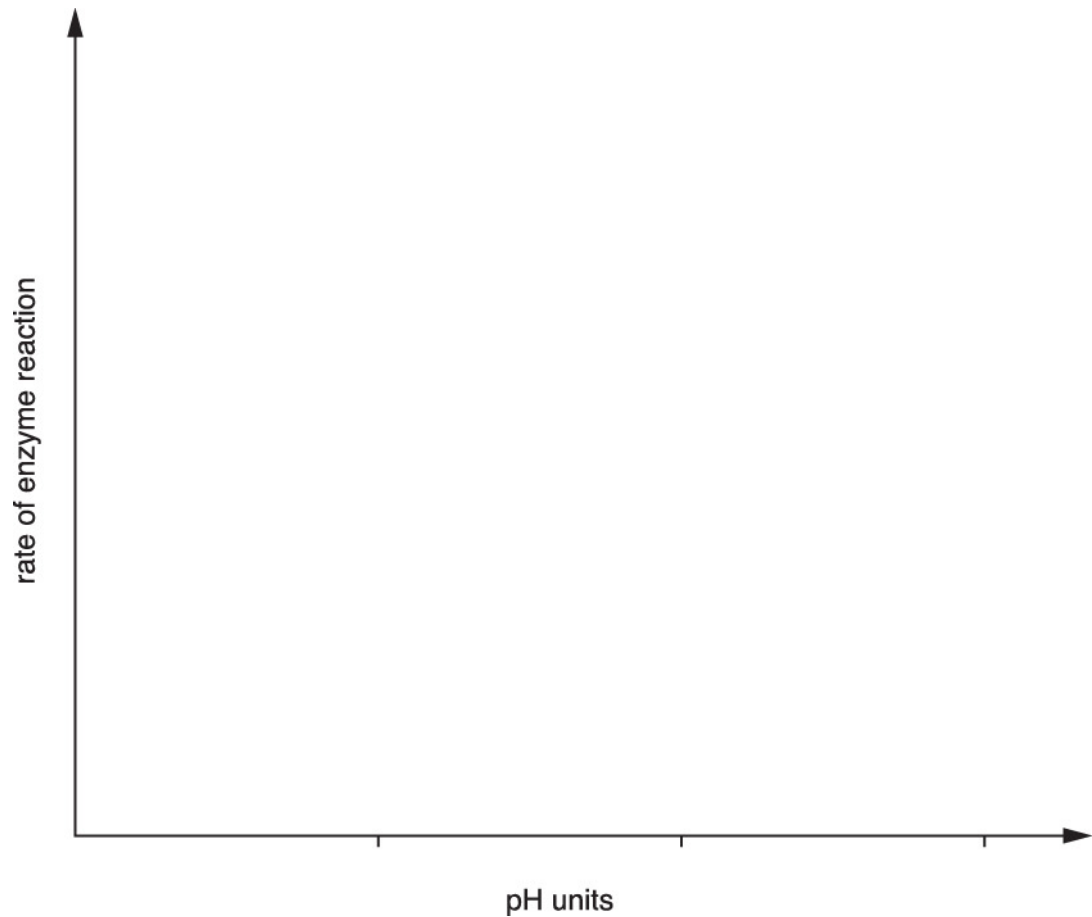
 In your answer, you should link the making and breaking of bonds between base pairs to the ability of DNA to replicate itself.

[illegible]

(c) The copying of DNA is catalysed by enzymes called polymerases.

Draw a curve, using the axes given below, to show how the rate of an enzyme catalysed reaction is affected by pH.

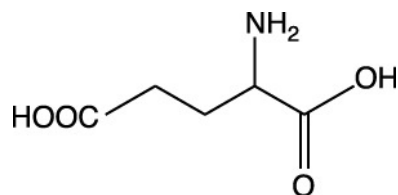
Label the optimum pH for the reaction.



[2]

(d) DNA codes for an amino acid sequence in a protein.

(i) Draw the **part of a protein chain** formed when two units of the amino acid shown below are joined together.

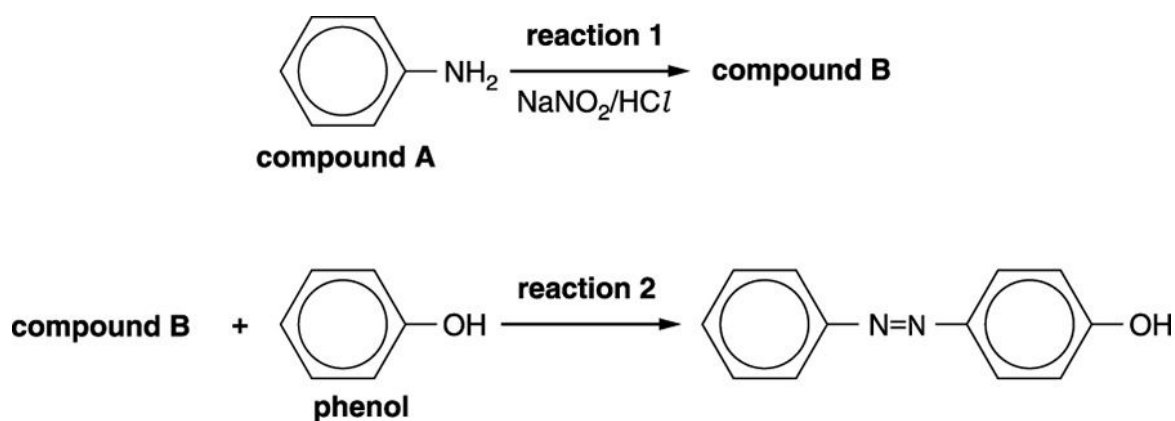


[1]

(ii) Explain the effect that increasing the pH has on the structure of the part of the protein formed in (i).

----- [1]

5 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]

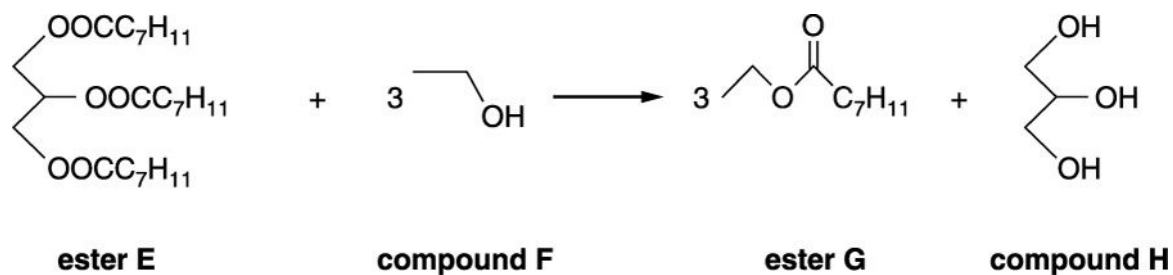
(iv) Phenol is acidic in solution. Carboxylic acids are also acidic but react in a way that phenols do not.

Give details of this acidic reaction of carboxylic acids.

-----[2]

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

One trans-esterification reaction is shown below.



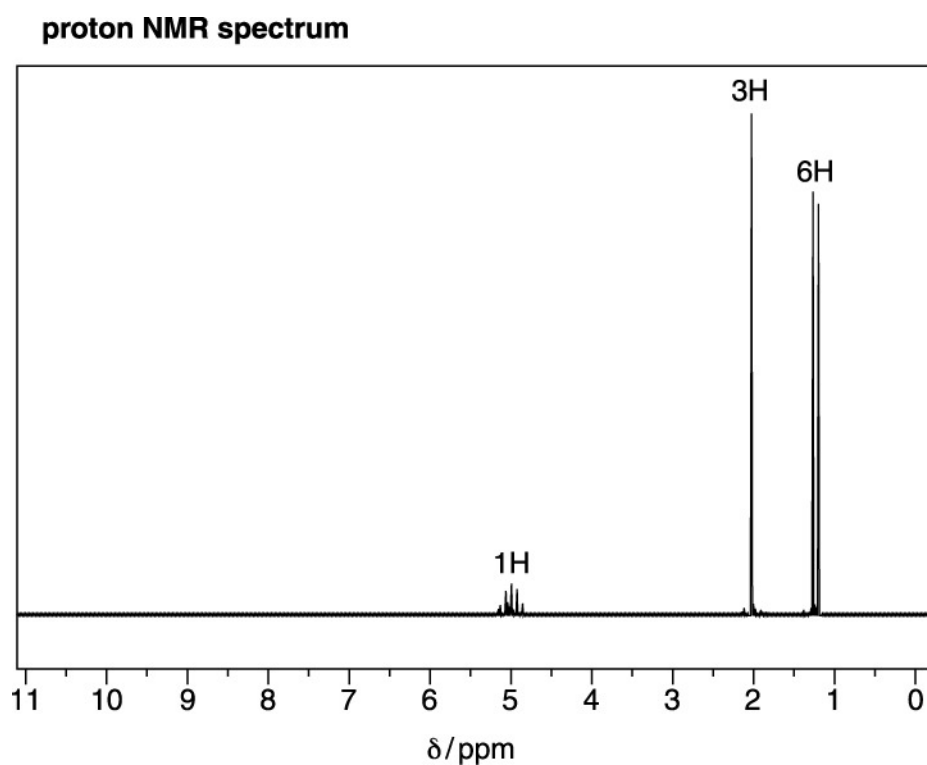
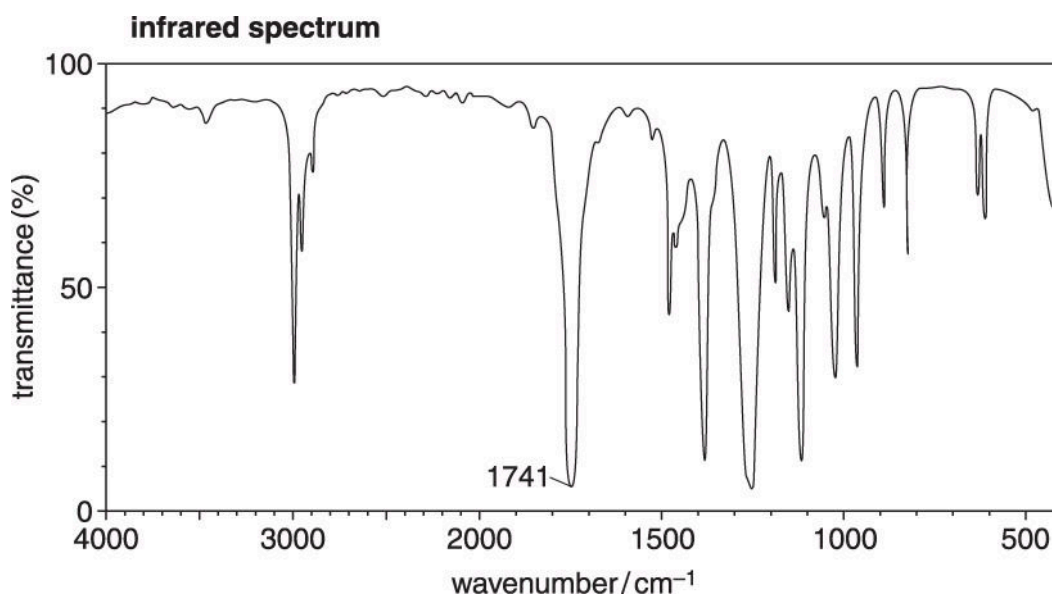
(i) Give the systematic name for compound F.

-----[1]

(ii) Give the systematic name for compound H.

-----[1]

- (b) Another ester J has the molecular formula $C_5H_{10}O_2$. The infrared and proton NMR spectra for ester J are given below.



You may use this page for working but all answers must be transferred to the lines in (i), (ii) and (iii).

- (i) $C_5H_{10}O_2$ has isomers that are acids.
One of these acids has a chiral centre.

Give the structure of this isomer, circling the chiral centre.

[2]

- (ii) Explain, using the infrared spectrum, why compound J cannot be an acid and is an **ester**.

[2]

- (iii) Use the NMR spectrum to work out the structure of ester J, $C_5H_{10}O_2$.

Give your reasoning.

Include in your answer an explanation of the doublet at a chemical shift of 1.2 ppm.

[5]

- 7 Scientists involved in the conservation of old leather books are concerned about the presence of acidic ammonium sulfate rotting the surface of the leather. This ammonium sulfate is formed by sulfuric acid from polluted air reacting with proteins in the leather.

Proteins contain -CONH_2 groups that react with aqueous sulfuric acid.

- (i) Name the -CONH_2 group.

----- [1]

- (ii) Complete and balance the equation below to show the reaction of this group with aqueous sulfuric acid to form ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$ and an organic product.



[2]

- (iii) Classify this reaction by circling one word from the list below.

addition

condensation

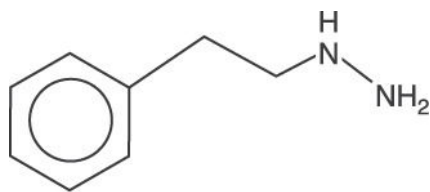
elimination

hydrolysis

substitution

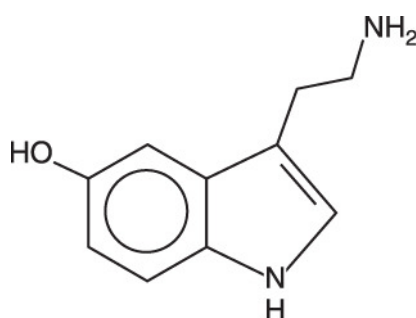
[1]

8(a) Phenelzine is an antidepressant drug.



phenelzine

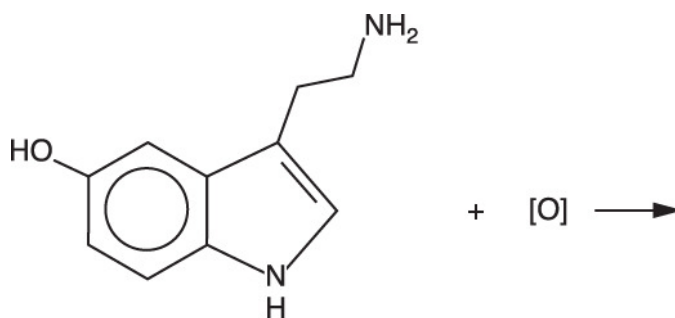
Phenelzine acts as an antidepressant because it irreversibly inhibits an enzyme. This enzyme catalyses the reaction of serotonin with an oxidising agent. Serotonin controls human mood.



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

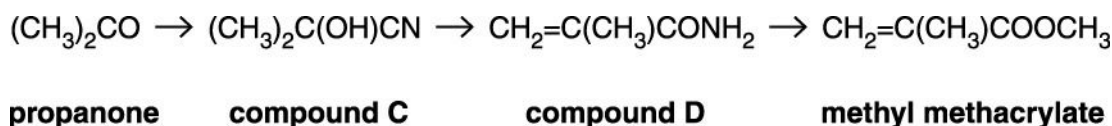
[2]

- 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.

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



- (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.

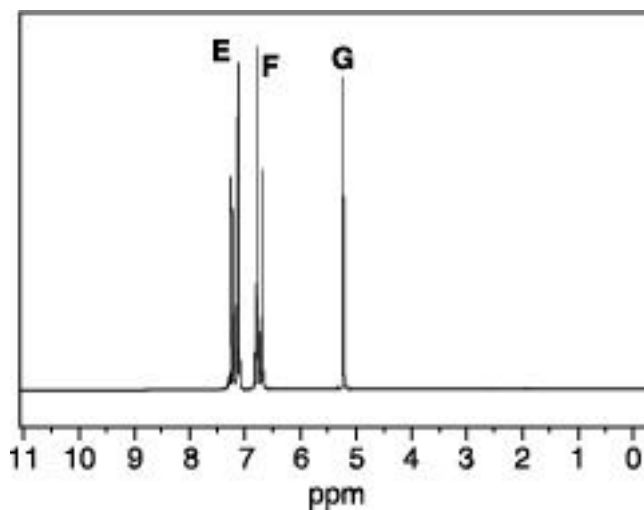
Type of polymerisation and reason

.....
.....

Repeat unit

[2]

(b) The proton NMR spectrum of one monosubstituted chlorophenol is given below.



(i) Explain why there are three peaks in the spectrum.

----- [1]

(ii) Draw the structure of the monosubstituted chlorophenol which produces this spectrum.

[1]

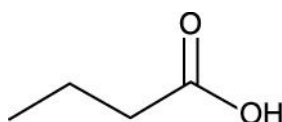
(iii) Label the relevant protons on the structure in part (ii) with E, F and G to correspond to the three peaks.

[2]

(iv) Explain why peaks E and F are doublets.

----- [1]

10(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) Esters of butanoic acid are used as food flavourings.
Methyl butanoate, for example, smells and tastes of pineapples.

(i) Draw the **skeletal** formula of methyl butanoate.

[1]

(ii) Methyl butanoate can be made in the laboratory by a one-step reaction using an acyl chloride.

Give the structure of the acyl chloride.

[1]

(iii) Name the types of intermolecular bonding in methyl butanoate.

Explain whether the ester has a higher or a lower boiling point than butanoic acid.



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

[3]

11 Which two compounds can react together to form a condensation polymer?

- A C_2H_4 and C_3H_6
- B $\text{C}_2\text{H}_5\text{OH}$ and CH_3COOH
- C $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$ and CH_3COOH
- D $\text{HOOC}(\text{CH}_2)_4\text{COOH}$ and $\text{HOCH}_2\text{CH}_2\text{OH}$

Your answer

☐

12 RNA is a polymer made of nucleotides. Nucleotides are monomers made of phosphates, sugars, and bases.

[1]

Which statement is correct about RNA?

- A Phosphate and deoxyribose units join together by a condensation reaction to form the phosphate–sugar backbone in RNA.
- B In RNA, adenine forms a base pair with thymine; cytosine forms a base pair with guanine.
- C Bases join to the phosphate–sugar backbone by a condensation reaction.
- D Base pairs form by a condensation reaction between the bases.

Your answer

☐

[1]

13 The process of protein synthesis involves DNA and RNA in the following steps.

- 1 An anti-codon on tRNA binds to a triplet code on mRNA.
- 2 A ribosome moves along a strand of mRNA.
- 3 DNA transcription occurs to make a strand of mRNA.
- 4 Amino acids carried by tRNA are assembled into a protein chain.

What is the correct order of these steps in protein synthesis?

- A 3 – 2 – 1 – 4
- B 3 – 1 – 2 – 4
- C 2 – 3 – 4 – 1
- D 1 – 3 – 4 – 2

Your answer

[1]

14 What template DNA sequence will produce the polypeptide GluValLeu?

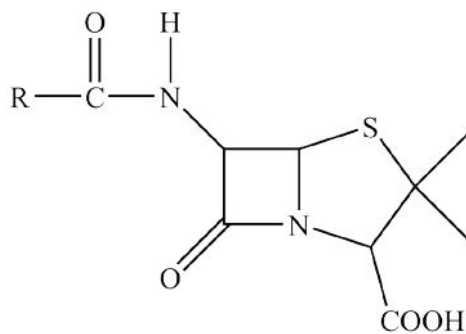
You may need to refer to your Data Sheet.

- A CUGGUCGAA
- B GTTCAGGAC
- C GUUCAGGAC
- D CAGGACTTC

Your answer

[1]

- 15 The diagram below shows the structure of a penicillin. The properties of the penicillin can be modified by changing the 'R' group side chain.



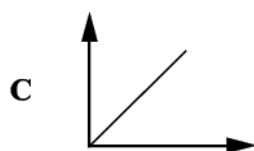
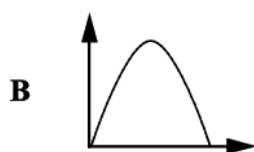
What name is given to the part of the drug that is medically active?

- A modifier
- B pharmacophore
- C receptor
- D chromophore

Your answer

[1]

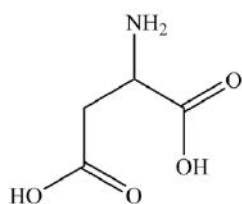
- 16 Which one of the following graphs correctly represents the shape of a rate versus substrate concentration plot for an enzyme-catalysed reaction?



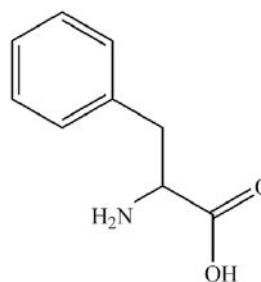
Your answer ☐

[1]

- 17 Aspartame is a sweetener which can be used instead of sugar. It is a methyl ester of a dipeptide formed from a reaction between the amino acids aspartic acid and phenylalanine, the structures of which are shown below.



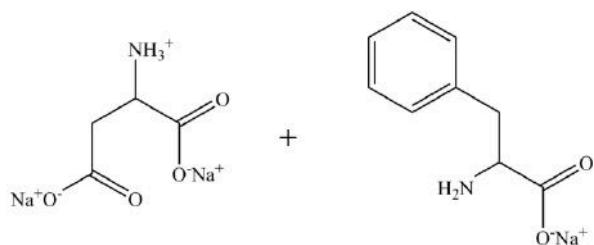
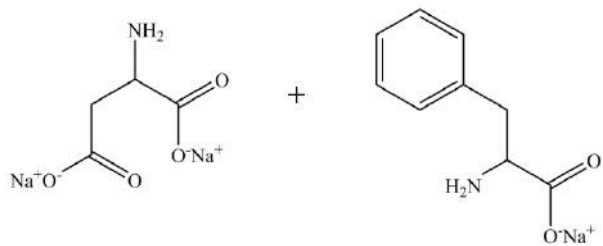
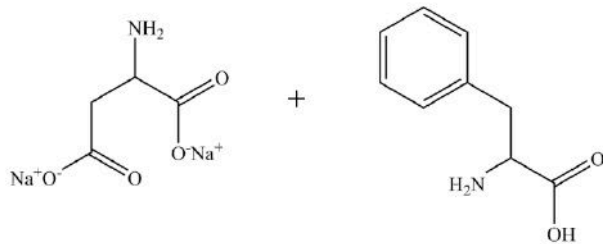
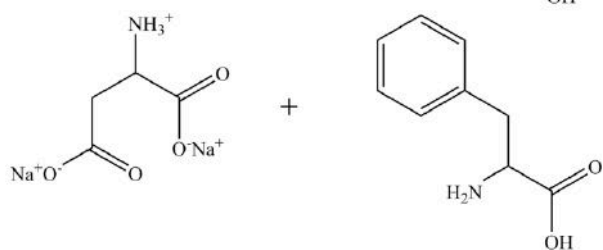
Aspartic acid



Phenylalanine

Alkaline hydrolysis of aspartame produces salts of the above amino acids.

Which pair of compounds is produced?

A**B****C****D**

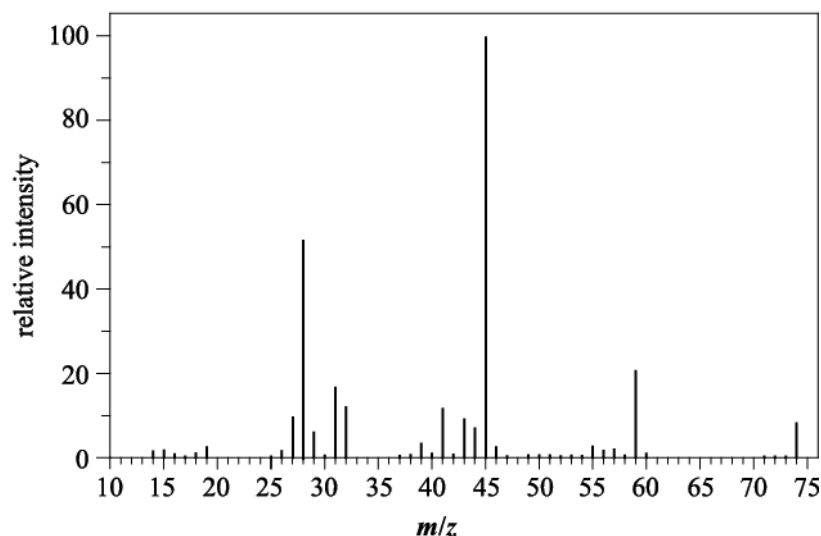
Your answer

[1]

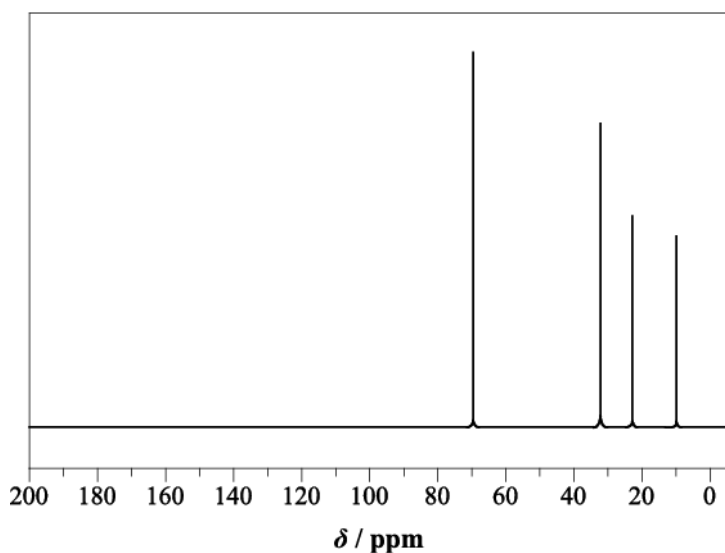
18(a) Ethanol is sometimes used as a biofuel to replace petrol in car engines. However it has several disadvantages.

* 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 .

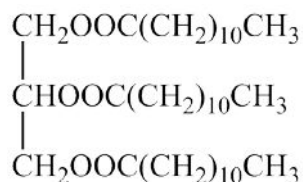
Compound **A** reacts with heated Al_2O_3 to form two unsaturated compounds, **C** and **D**.

[illegible]

(b) The electricity-tolerant bacteria used to convert methanoic acid contain an enzyme used to synthesise compound **A**. This enzyme is specific to this synthesis.
Explain why an enzyme is specific for a particular reaction.

[2]

- 19 Coconut oil contains a large amount of compound E. The sodium salt, F, of compound E is used as a soap.

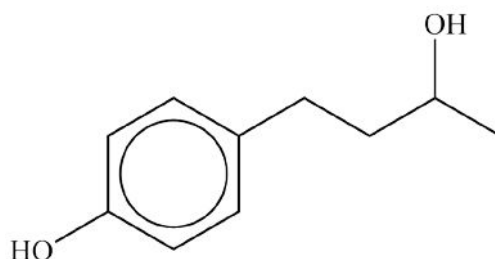


Compound E

Circle an ester group on the diagram of the structure of E above.

- 20 Raspberry ketone, extracted from various berries, is widely used as a flavouring, a constituent of perfumes and as a diet supplement. [1]

Raspberry ketone can be reduced to the compound shown below.



Explain why this compound has two stereoisomers and describe how they differ.

----- [2]

21 What is correct about RNA?

- A RNA codes for DNA.
- B RNA has the same bases as DNA.
- C Triplets in RNA code for amino acids.
- D RNA contains a deoxyribose-phosphate backbone.

Your answer

[1]

22 Which statement is correct about amines?

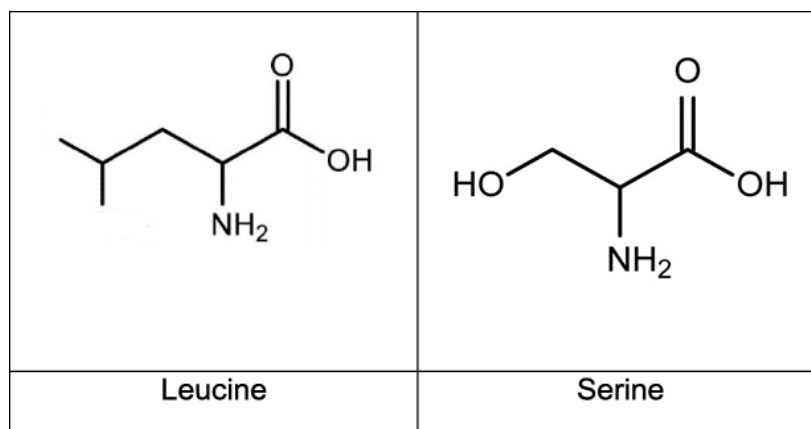
- A They react with organic acids to form amides.
- B They react with strong acids to form anions.
- C They have a lone pair of electrons they can donate.
- D They are neutral in solution.

Your answer

[1]

23(a) Proteins are vital constituents of our bodies. They are made from amino acids.

Two different amino acids are shown below.



Draw the **skeletal** structures of **two** different dipeptides formed between leucine and serine.

[3]

(b) Both these amino acids exhibit optical isomerism.

Draw the structures of the **two** optical isomers of serine.

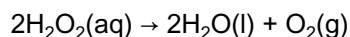
[2]

- (c) Amino acids can polymerise to proteins, some of which are enzymes.

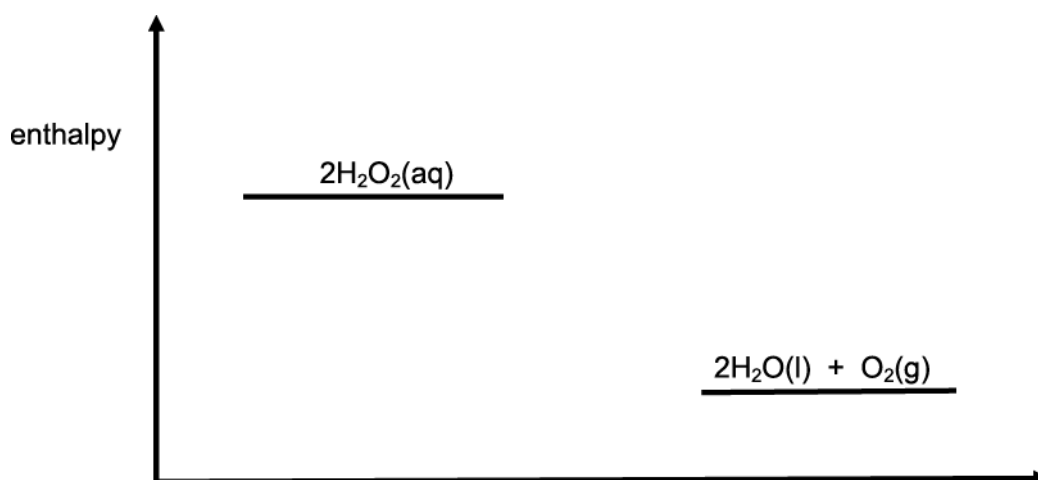
Describe and explain how the structure of enzymes helps them to catalyse reactions.

----- [2]

- (d) Catalase is an enzyme which catalyses the breakdown of toxic hydrogen peroxide in the body.



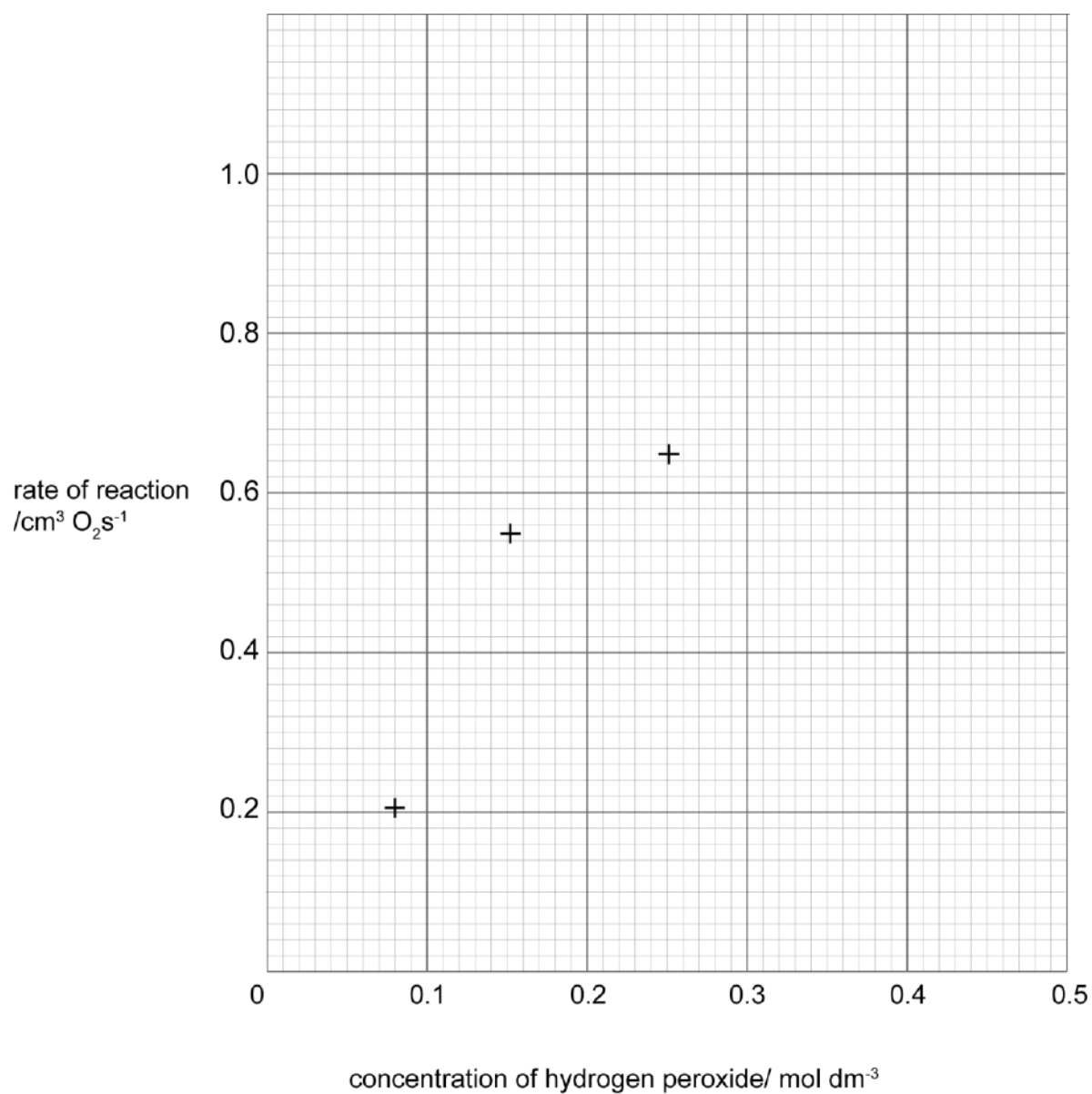
Complete the enthalpy profile to show the reactions with and without the enzyme as catalyst.



- (e) The students carry out a series of experiments with different concentrations of hydrogen peroxide and catalase with a concentration of 1%. They obtain the results shown in the table below. [1]

Concentration of hydrogen peroxide / mol dm ⁻³	Rate of reaction / cm ³ O ₂ s ⁻¹
0.08	0.201
0.15	0.552
0.25	0.645
0.33	0.833
0.42	0.900
0.50	0.911

Complete the plot of rate against concentration on the grid below and draw the line of best fit.



- Comment on the students' conclusions, using evidence from the graph.
Give the correct chemistry where necessary.

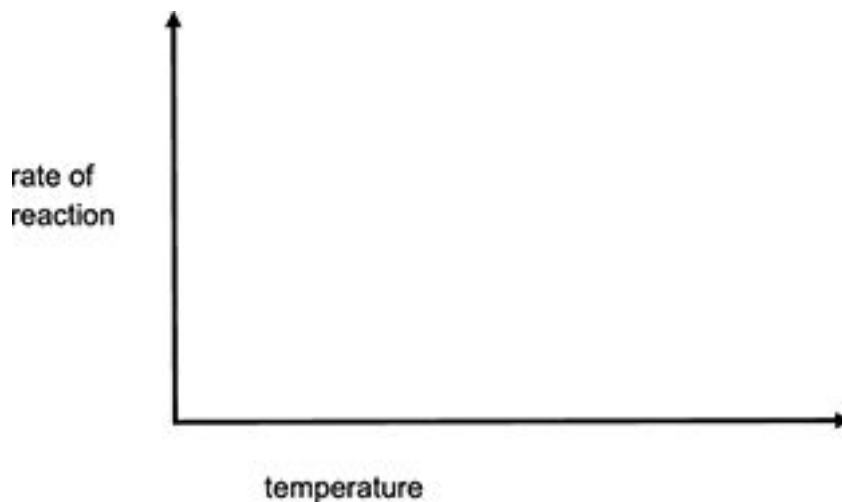
Give the correct chemistry where necessary.

[6]

(g) Catalase is an enzyme.

The students carry out the reaction at different temperatures and measure the initial rate of reaction.

Sketch the graph of the expected results and explain your answer.



[3]

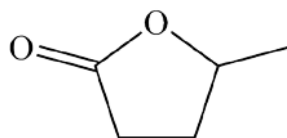
(h) Give **one** advantage and **one** disadvantage of using enzymes in industrial processes.

Advantage -----

Disadvantage -----

[2]

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



GMV

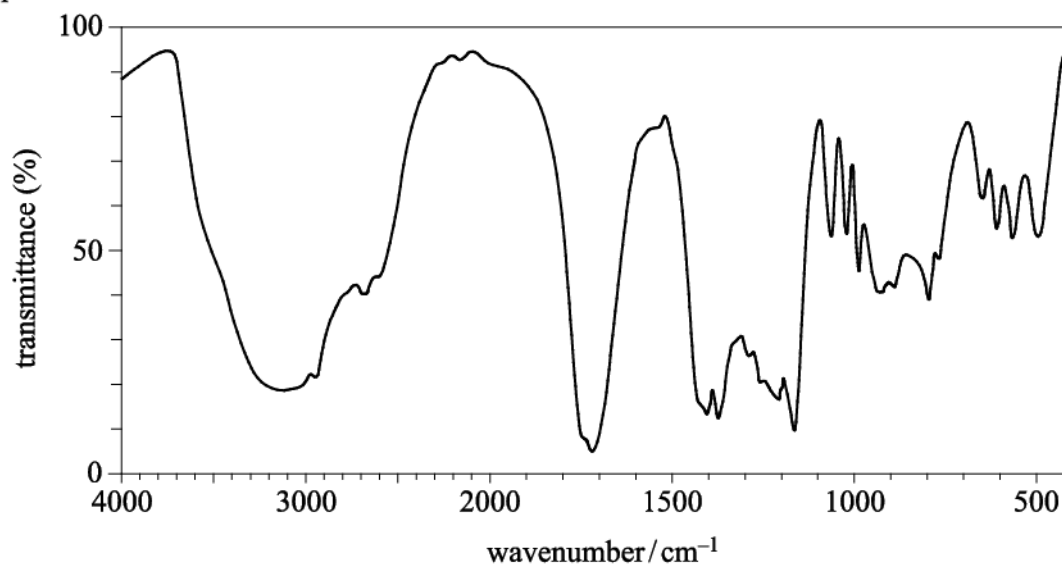
* Compound **G** is an intermediate in the manufacture of GMV from glucose.

Compound **G** has the following composition by mass:

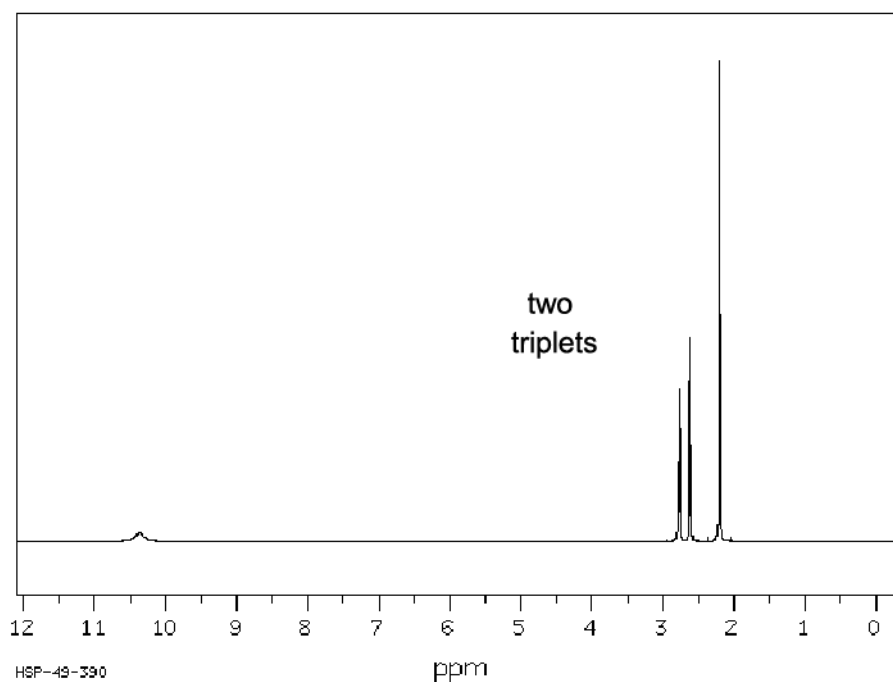
C, 51.72%; H, 6.90%; O, 41.38%

Compound **G** has IR and ^1H NMR spectra as shown below.

IR spectrum:



^1H NMR spectrum:



Use all this information to work out the structure of compound G.

In your answer give evidence to support your choice of structure.

[6]

- (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**).

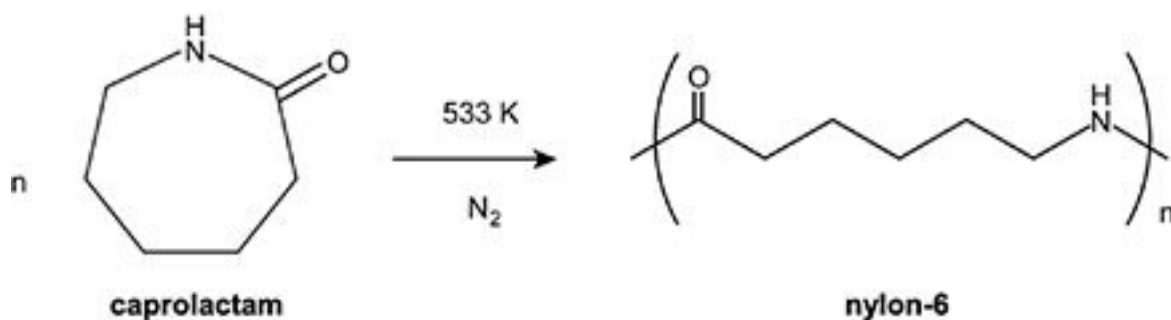
----- [2]

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

----- [6]

26(a) Nylon-6 is also used to wrap food.

Nylon-6 is formed by polymerising 'caprolactam'.



(i) Name the functional group in caprolactam.

----- [1]

(ii) Give the meaning of the '6' in nylon-6.

----- [1]

(iii) Explain why the reaction of caprolactam to nylon-6 is **not** condensation and suggest how the reaction is classified.

----- [2]

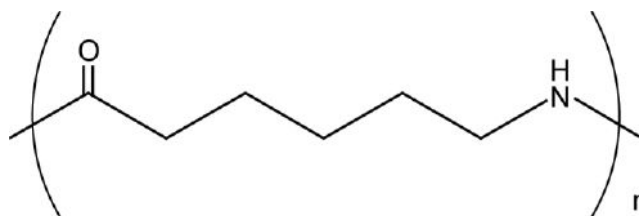
(iv)

Nylon-6 can be used at much higher temperatures than PVC without softening.

Suggest a reason for this in terms of intermolecular bonds.

----- [4]

(b) Some students carry out acid hydrolysis on a sample of nylon-6.



Nylon-6

(i) Suggest the reagent and conditions they use.

reagent: _____

conditions: _____

[2]

(ii) The students obtain a product, compound **A**, that is not cyclic.

Compound **A** is formed by the acid hydrolysis of nylon-6.

Give the formula of compound **A**.

[1]

(iii) Compound **A** will not polymerise to nylon-6.

Compound **A** can be neutralised and then changed to compound **B**.

Compound **B** will polymerise at room temperature to form nylon-6.

Give the structure of compound **B** and name the new functional group it contains.

Compound **B**

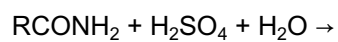
Name of functional group: _____ [2]

- 27 Scientists involved in the conservation of old leather books are concerned about the presence of acidic ammonium sulfate rotting the surface of the leather.

The ammonium sulfate is formed by sulfuric acid from polluted air reacting with proteins in the leather.

Proteins contain CONH_2 groups.

Complete and balance the equation below to show the reaction of this group with aqueous sulfuric acid to form ammonium sulfate and an organic product.



[2]

28(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.

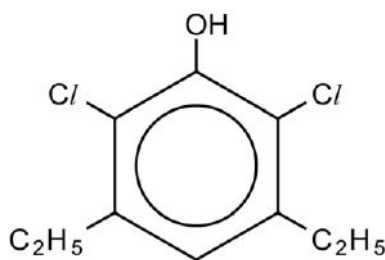
- (i) Name the functional group.

-----[1]

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

-----[2]

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.

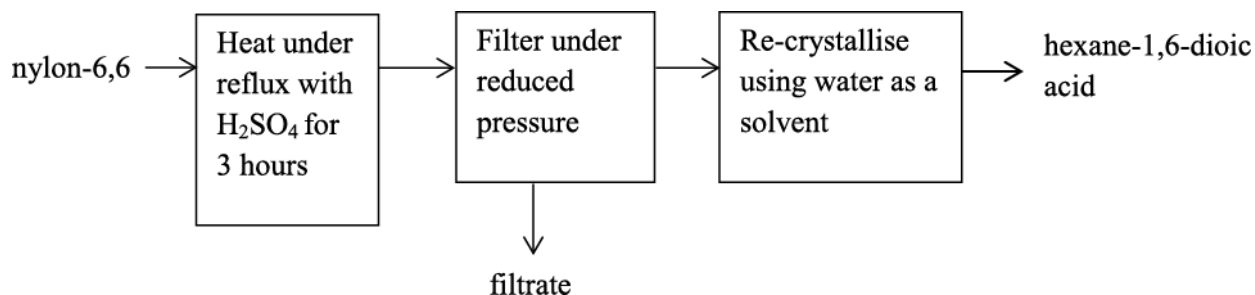
Name the intermolecular forces broken in the solvent in each case.

water -----

non-polar solvents -----

[2]

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



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

----- [2]

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

[3]

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

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

[4]

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

Calculate the percentage yield of the reaction.

yield = ----- % [2]

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

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

[1]

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

The student follows the procedure given below.

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

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

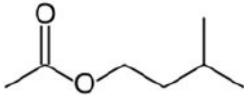
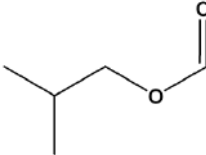
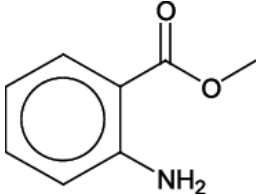
-----[1]

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

-----[1]

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

Complete the table below by filling in the blanks.

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

[3]

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

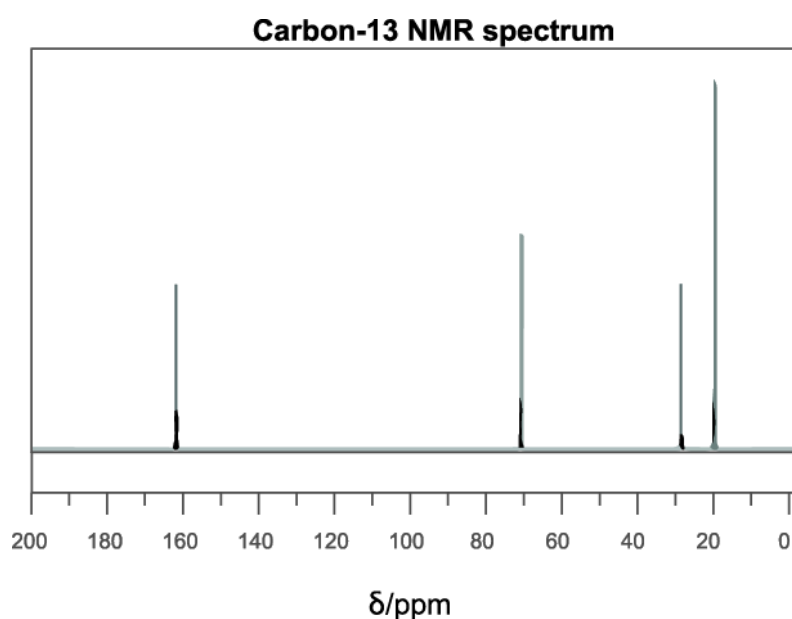
The student repeats the procedure with a larger quantities of reactants. After adding the sodium carbonate the student:

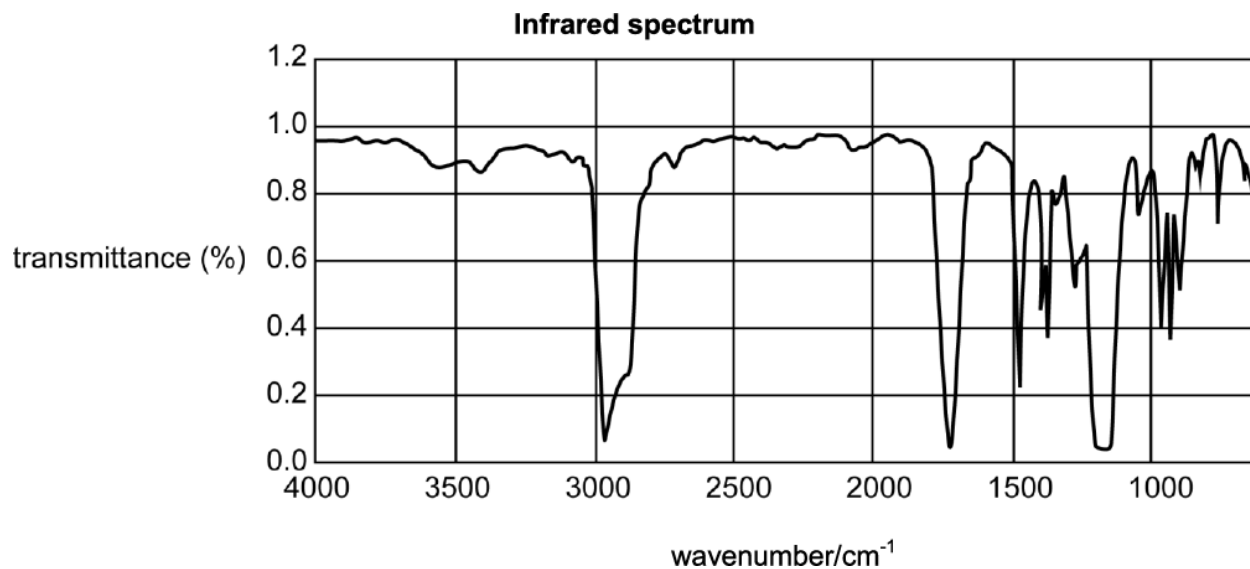
- puts the reaction mixture into a separating funnel and runs off the bottom aqueous layer
- swirls the top ester layer with anhydrous sodium sulfate for 20 minutes
- distils the mixture, collecting the ester.

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

-----[1]

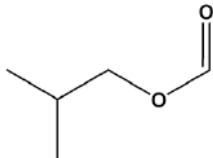
- (ii) * The student gets a local laboratory to run a carbon-13 NMR and an infrared spectrum on the product to confirm whether the preparation had produced the pure raspberry ester.





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

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

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

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

[6]

32(a) Trypsin is an enzyme used by bread producers to partially hydrolyse the protein, gluten, present in wheat.

The primary structure of a protein can be described as a series of amino acid *residues*. A residue is the structure of the amino acid after it has been incorporated into a protein chain.

Describe what is meant by the *secondary* and *tertiary* structures of a protein.

secondary -----

tertiary -----

----- [2]

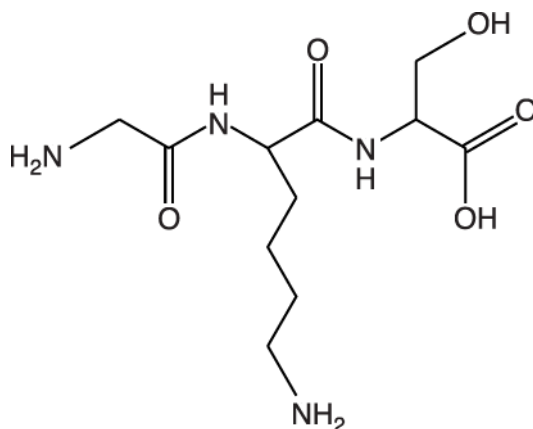
(b) Trypsin has an active site.

Describe an *active site* and give its function.

----- [3]

- (c) Trypsin only catalyses the hydrolysis of amide links where the C=O is part of a lysine residue. The 'R' group in lysine is $-(CH_2)_4NH_2$.

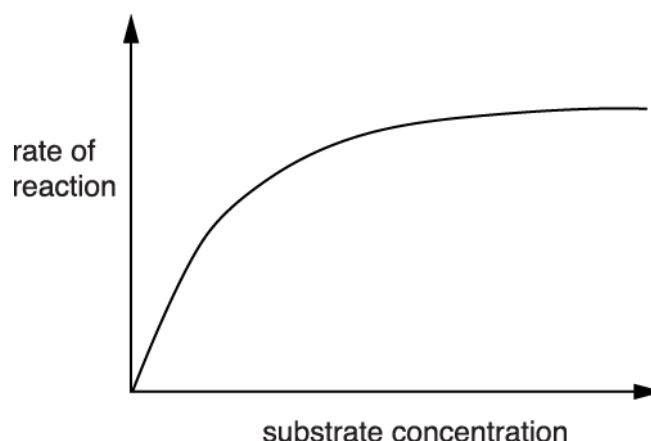
Trypsin partially hydrolyses the tripeptide shown below.



Draw the products of this partial hydrolysis once the solution has been neutralised.

[3]

- (d) A student investigates how the rate of hydrolysis at 37 °C changes with the concentration of substrate protein. A graph of the student's results is shown below.



- (i) The mechanism of the reaction can be represented by the equations:

1. $E + S \rightleftharpoons ES$
2. $ES \rightarrow E + P$

The symbols S, E and P represent the substrate, enzyme and products respectively.

Use ideas of reaction orders, rate-determining steps and active sites to explain the shape of the graph.



In your answer, you should indicate how the shape of the graph relates to the equations.

[5]

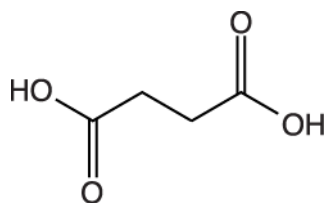
- (ii) The student repeats the experiment for trypsin at 70 °C, well above the optimum temperature, which is 40 °C.

Describe the appearance of the graph of rate of reaction against substrate concentration at 70 °C.

Explain your answer.

----- [2]

33(a) Polymers made using succinic acid and ethane-1,2-diol were first synthesised in 1863. In the 1930s, these polymers were further investigated by Wallace Carothers as possible alternatives to silk. He later abandoned the project in favour of researching polyamides, which he thought would be stronger.



Succinic acid

- (i) Draw the structural formula of the repeating unit of the polymer produced using succinic acid and ethane-1,2-diol.

[1]

- (ii) Give the name of this type of condensation polymer.

-----[1]

- (iii) Circle in your repeating unit the group of atoms responsible for this type of polymer.

[1]

(b)

- (i) Suggest why Carothers thought that polyamides would form stronger fibres than the polymer in (a)(i).

In your answer, refer to **all** the types of intermolecular bonds present in the two types of polymer.

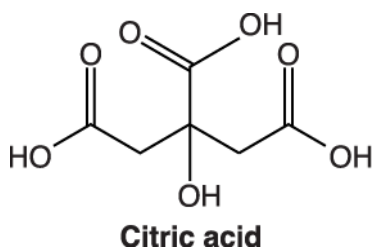
[4]

- (ii) The strength of polyamide fibres is improved by the process of cold drawing.

Describe the process of cold drawing and explain how this makes the fibres stronger.

[3]

- (c) Recently, polymers containing citric acid and **compound C** have been developed.



- (i) Give the systematic name for **compound C**.

[1]

- (ii) Draw the structure of part of the chain formed from **two** molecules of compound C and **one** molecule of citric

acid.

[2]

(iii) These polymers are water-soluble.

Suggest why they are water-soluble.

----- [1]

(iv) The polymers can protect human cells from damage at freezing temperatures.

Give **two** questions that clinical trials would have to answer before the polymers could be used as medicines.

1.

2.

----- [1]

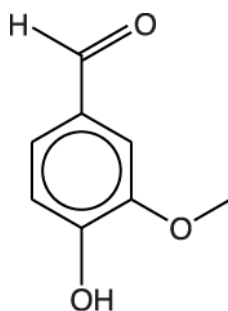
(v) **Compound C** can act as a base.

Explain how **compound C** acts as a base.

----- [2]

34(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.

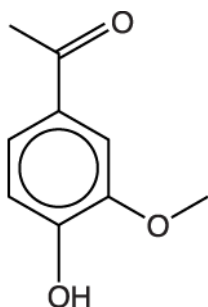
----- [2]

(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.

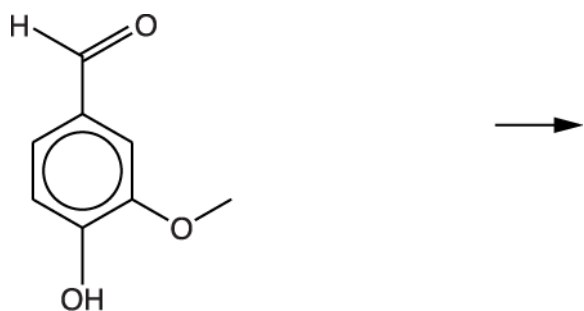


In your answer, you should use appropriate technical terms, spelled correctly.

[3]

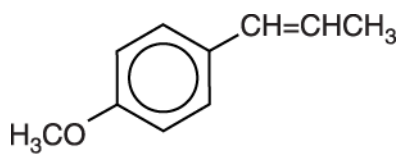
(c) Vanillin reacts with cyanide ions and dilute acid.

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]

35(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.

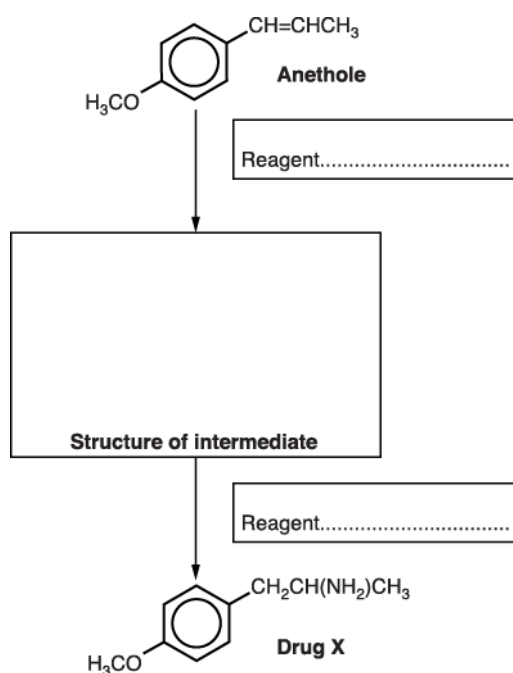
Explain this statement in terms of hydrogen bonding, indicating how these bonds are formed.

[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]

36(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:

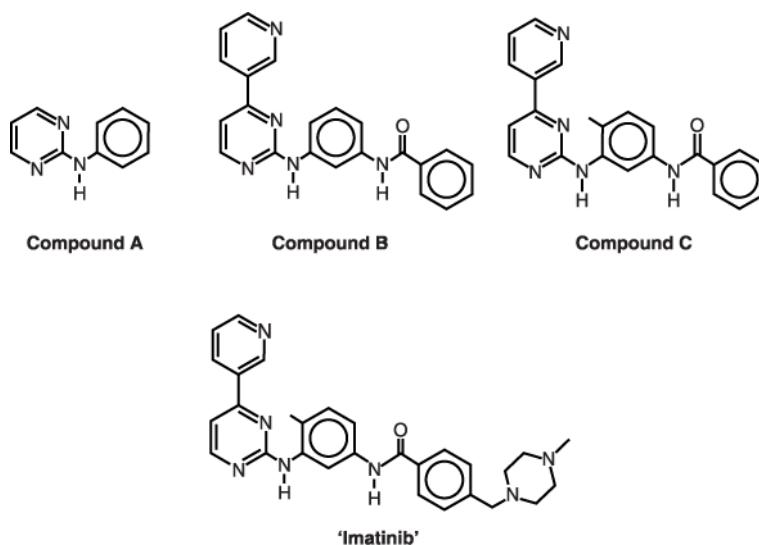
a suitable substance for the mobile phase

the nature of the stationary phase

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

37(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.

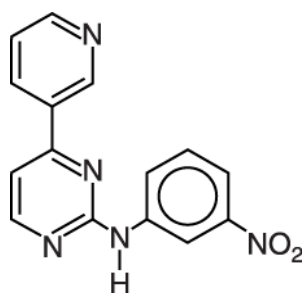
Suggest why compound C is more specific than compound B.



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.

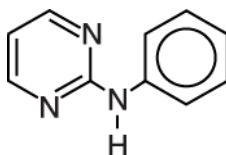
Name the functional group formed, and give the formula and name of a suitable reagent.

name of functional group formed -----

formula of reagent -----

name of reagent ----- [3]

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

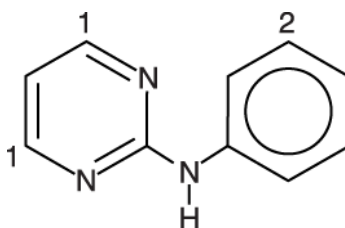


Compound A

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

-----[1]

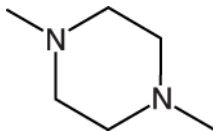
(ii) Indicate the number of peaks in the proton NMR of compound **A** by using numbers for each different proton environment on the structure below. Some numbers have been added already.



Compound A

[2]

(e)



The ring structure is not planar.

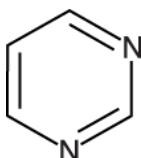
State a value for the bond angle and name the shape around the nitrogen atoms in the structure. Explain how this bond angle arises.

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.

(f)



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

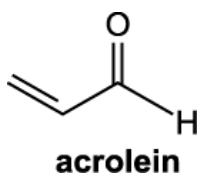
Suggest how the electrons are arranged in this structure.

[3]

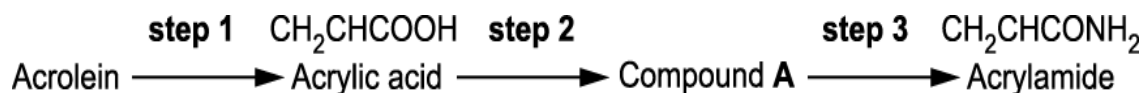
[5]

- 38 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.



Acrolein can be converted to 'acrylamide' in a laboratory, using the pathway below.



- (i) Draw the **full** structural formula of compound A, which is an acyl chloride.

[1]

- (ii) Give suitable reagents for steps 2 and 3.
(You may need to refer to the *Data Sheet*)

step 2:

step 3:

[2]

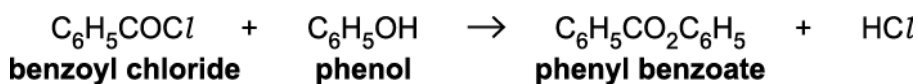
- (iii) A student obtains 0.55 g of acrylamide from acrolein (M_r 56.0) using this pathway and calculates that this is a 3.0% yield.

Calculate the mass of acrolein that the student started with.

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

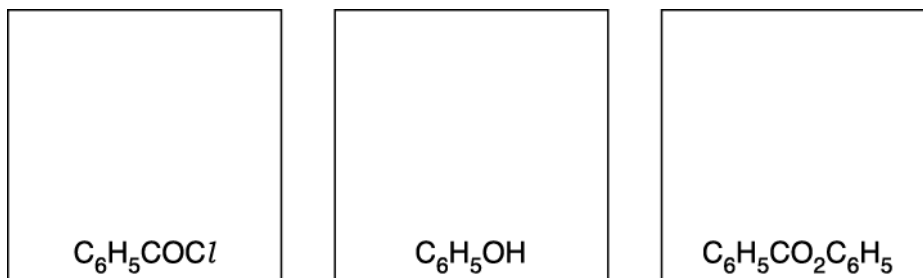
mass = ... g [2]

39 Two students aim to prepare a sample of phenyl benzoate using the reaction below.



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

[1]



40 A dipeptide is hydrolysed by heating with moderately concentrated hydrochloric acid. The products of hydrolysis are then analysed using paper chromatography.

Which statement is **not** correct?

- A Dots of the hydrolysis mixture, together with the likely amino acids present, are put on a pencil line on the paper.
- B The spots can be made visible by spraying with ninhydrin.
- C The R_f value can be found from:

$$\frac{\text{distance of solvent front from baseline}}{\text{distance of spot from baseline.}}$$

- D At the start the solvent must not touch the baseline on the chromatography paper.

Your answer

[1]

41 A medicine can inhibit the function of an enzyme, slowing down the reaction of a substrate.

What is correct about the medicine molecules?

- A They have the same shape as the active site of the enzyme.
- B They react in the active site.
- C They fit into the active site.
- D They have a complementary shape to the substrate.

Your answer

[1]

42 A polymer has the repeat unit shown.



What is/are the correct monomer(s) for the polymer?

- A $\text{HOOC(CH}_2\text{)}_3\text{COOH}$
- B $\text{HOOC(CH}_2\text{)}_3\text{OH}$
- C HOCH=CHOH and $\text{H}_2\text{C=CH}_2$
- D $\text{HO(CH}_2\text{)}_4\text{OH}$

Your answer

[1]

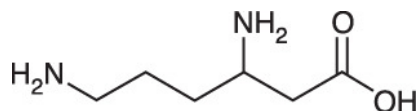
43 What is **not** correct about the amino acid $\text{H}_2\text{NCH}_2\text{COOH}$?

- A It reacts with both CH_3COCl and CH_3OH .
- B It has a chiral centre.
- C It forms zwitterions.
- D It is able to form condensation polymers with other similar molecules.

Your answer

[1]

44 The amino acid beta-lysine has the structure shown.



25.0 cm³ of a 0.0100 mol dm⁻³ solution of beta-lysine is titrated separately with 0.0150 mol dm⁻³ hydrochloric acid and 0.0200 mol dm⁻³ sodium hydroxide.

Which row represents the correct volumes of solution that react with the lysine?

	Volume 0.0150 mol dm ⁻³ HCl/cm ³	Volume 0.0200 mol dm ⁻³ NaOH/cm ³
A	8.33	50.0
B	16.7	12.5
C	33.3	12.5
D	33.3	25.5

Your answer

[1]

45 Which statement(s) about DNA and RNA is / are correct?

- 1 A nucleotide is composed of a phosphate, a sugar and a base.
- 2 Guanine and cytosine are joined by 3 hydrogen bonds in DNA.
- 3 Adenine and thymine are joined by 2 hydrogen bonds in RNA.

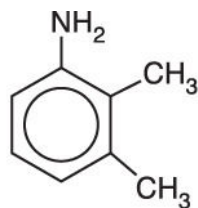
- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

[1]

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

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



2,3-dimethylphenylamine

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

----- [3]

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

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

[1]

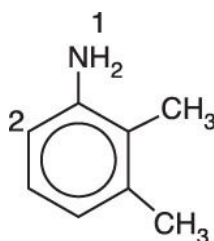
(iii) The aqueous layer is then run off.

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

----- [2]

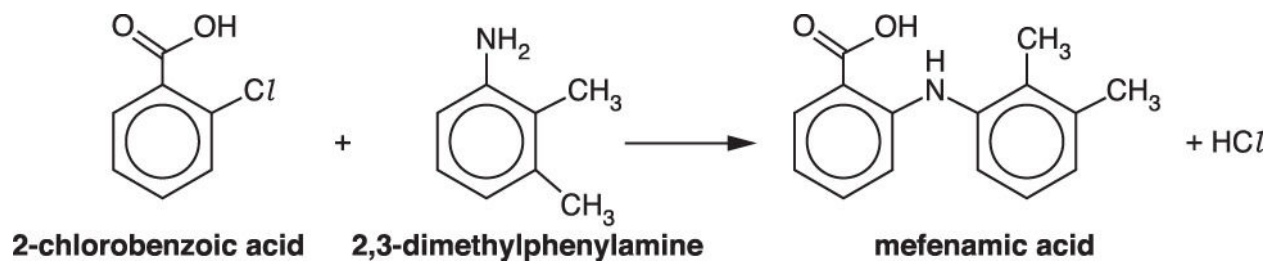
(b) Indicate the number of peaks in the proton NMR spectrum for 2,3-dimethylphenylamine. Use numbers for each proton environment on the structure below.

Some numbers have been added already.



[2]

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



The yield of the reaction is 52%.

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

mass = _____ kg [3]

- (d) *The structure of mefenamic acid can be investigated by a combination of spectroscopic techniques.

Describe and explain the appearance of the infrared spectrum and mass spectra, and how they could be used to identify mefenamic acid.

[6]

47(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.

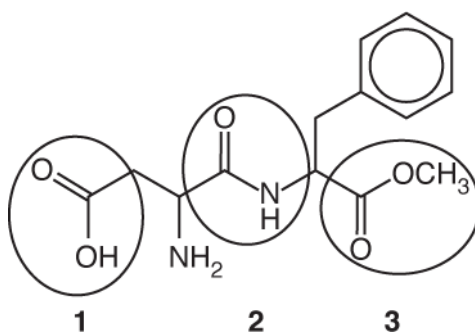
They then cautiously boil the contents for about a minute.

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 -----

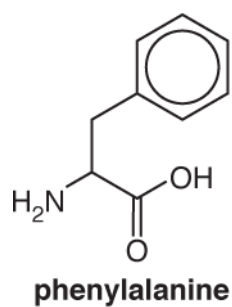
[1]

(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**.



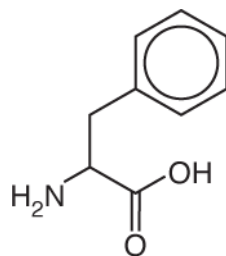
structure of **ion** formed by aspartic acid

[2]

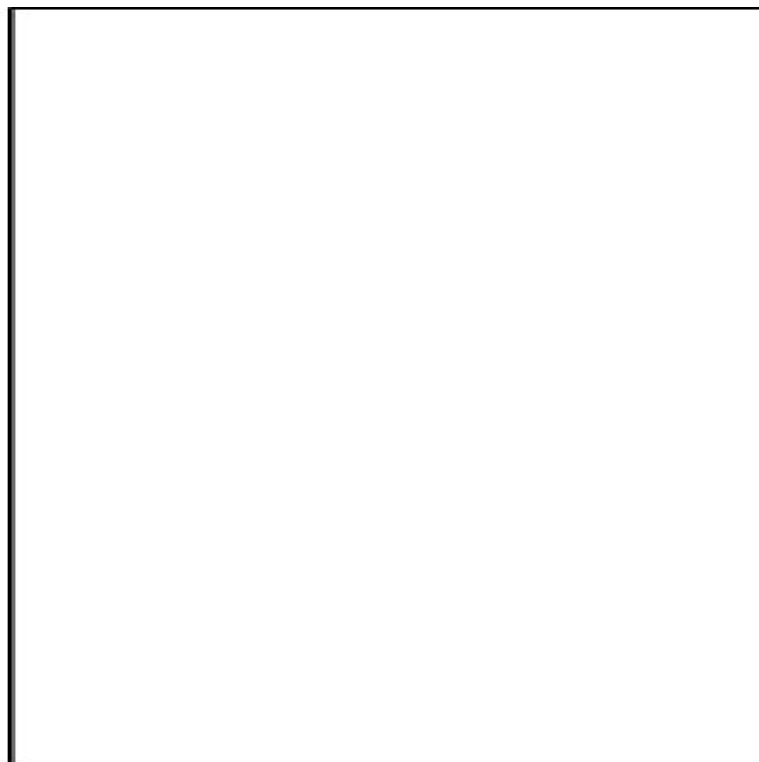
(iii) Amino acids such as phenylalanine exist as *zwitterions*.

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

Draw the structure of the zwitterion of phenylalanine.



phenylalanine



A large empty rectangular box with a black border, intended for drawing the zwitterion structure of 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 DNA is a condensation polymer.

B Adenine and uracil join by 2 hydrogen bonds in DNA.

C Guanine and cytosine join by 3 hydrogen bonds in DNA.

D The backbone of DNA is made of phosphate and deoxyribose.

7

[1]

49 Which statement describes the secondary structure of a protein?

- A the types of amino acids present
- B the sequence of the amino acids
- C attractions between groups causing folding of the protein helix
- D hydrogen bonds causing a helix or sheet

Your answer

[1]

50 What is correct for reactions involving enzymes?

- A The enzyme works best at high temperature.
- B The rate is zero order with respect to substrate at low substrate concentration.
- C The half-life for the substrate is always constant.
- D The rate is zero order with respect to substrate at high substrate concentration.

Your answer

[1]

51 Which pair will **not** react together?

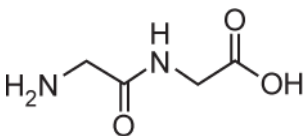
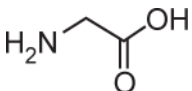
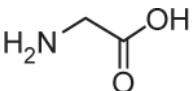
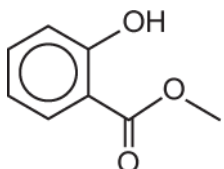
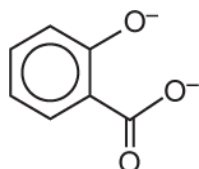
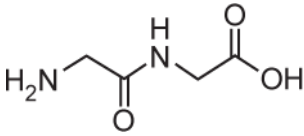
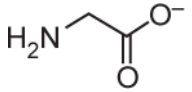
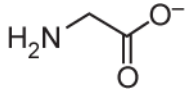
- A $(\text{CH}_3)_3\text{CCOC/}$ and $(\text{CH}_3)_3\text{CNH}_2$
- B $\text{CH}_3\text{COC/}$ and CH_3OH
- C $(\text{CH}_3)_3\text{N}$ and $\text{CH}_3\text{COC/}$
- D $\text{C}_6\text{H}_5\text{OH}$ and $(\text{CH}_3)_3\text{CCOC/}$

Your answer

[1]

52 Some organic reagents are hydrolysed under either acidic or alkaline conditions.

Which row(s) show(s) the correct products of the hydrolysis reactions?

	Reagent	Conditions	Product 1	Product 2
1		Acidic		
2		Alkaline		CH ₃ OH
3		Alkaline		

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

Your answer

[1]

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

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

(i) Write an equation for this reaction.

[2]

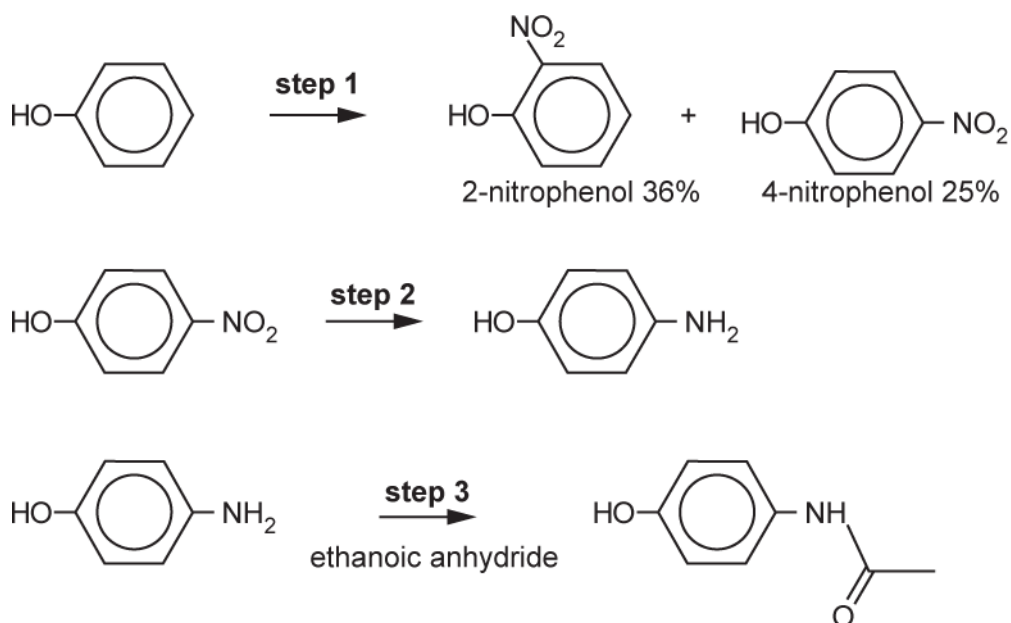
(ii) Calculate the volume (in cm^3) of $0.500 \text{ mol dm}^{-3}$ Na_2CO_3 that would react with 25.0 cm^3 of $0.450 \text{ mol dm}^{-3}$ CH_3COOH .

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

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

[1]

54(a) 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]

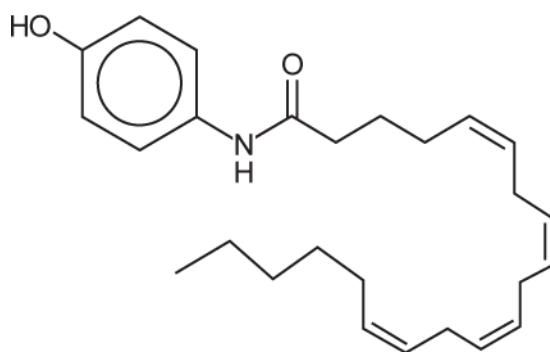
(v) The students purify the product from **step 3** by recrystallisation from water.

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

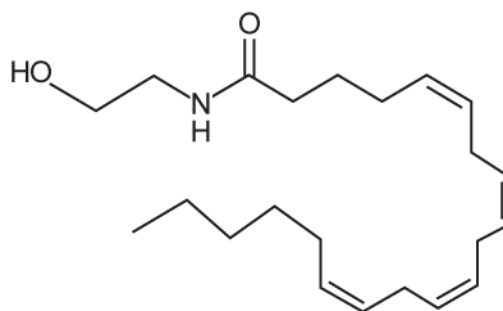
----- [4]

(b) Paracetamol is thought to be converted to AM404 in the body.

AM404 is thought to inhibit the enzyme-catalysed breakdown of anandamide. Anandamide reduces pain responses.



AM404



anandamide

(i) Suggest how AM404 inhibits the breakdown of anandamide.

----- [3]

(ii) Describe the stereochemistry of the double bonds in AM404.

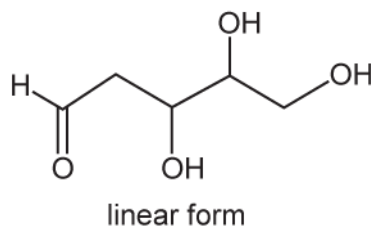
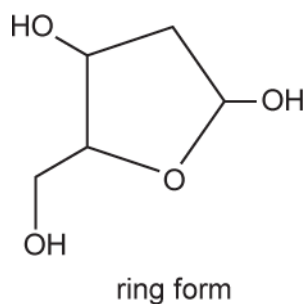
----- [1]

(iii) Explain how the double bonds in AM404 hold the carbon chain in shape.

----- [1]

55(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]

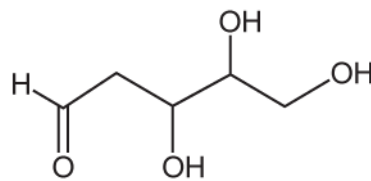
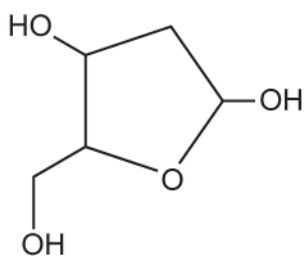
(ii) Name the functional group that is present in the linear form only.

-----[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]

(c) The structure of a fragment of DNA is sometimes represented by a sequence of letters, e.g. GCA. The letters stand for guanine, cytosine and adenine.

- (i) What single term describes guanine, adenine and cytosine?
How and where do they attach to the sugar-phosphate backbone?

term -----

----- [2]

- (ii) Give the DNA sequence that would produce the CUG sequence in RNA.

----- [1]

- (iii) The sequence given in (c)(ii) codes for an amino acid in a protein chain.

Name the amino acid. Use the *Data Sheet* to help you.

----- [1]

- (iv) Explain how a sequence in DNA codes for an amino acid.

----- [2]

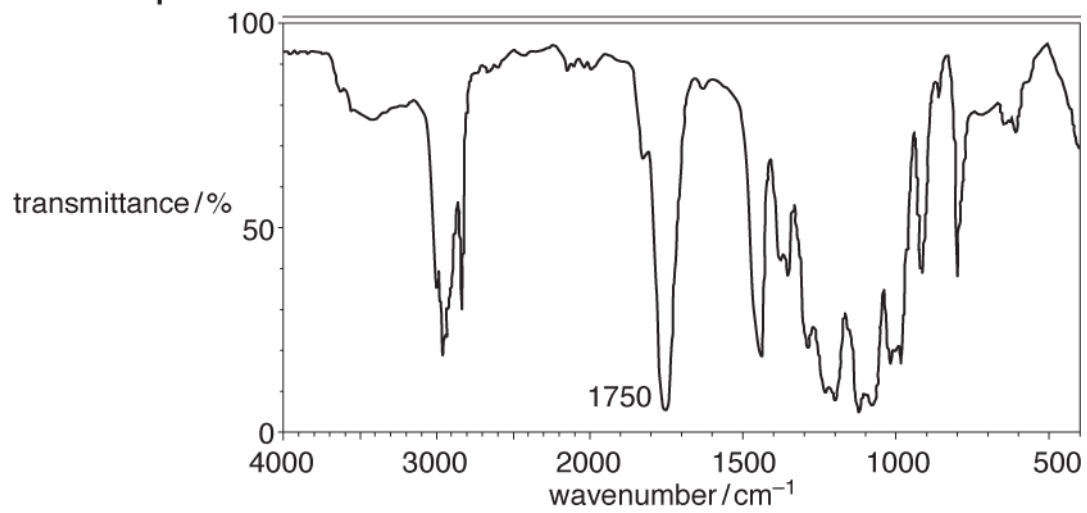
(d)



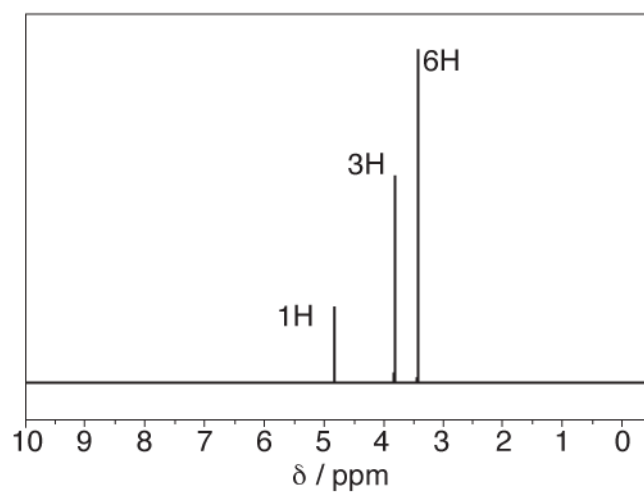
Compound **B** is a structural isomer of deoxyribose with the molecular formula $C_5H_{10}O_4$.

The infrared, ^1H and ^{13}C NMR spectra of compound **B** are shown below.

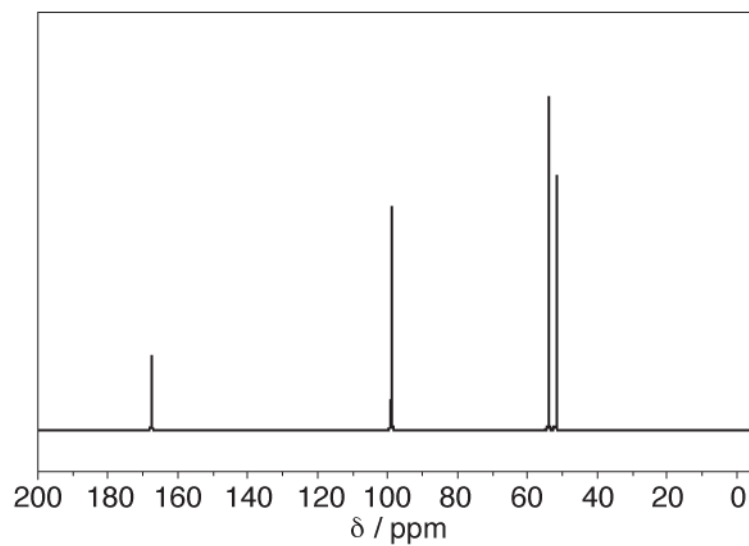
Infrared spectrum



^1H NMR spectrum



^{13}C NMR spectrum



Give evidence from **each** spectrum and show how it relates to the structure you have given.

[6]

56 Which statement is **not** correct about amines?

- A The lone pair on the nitrogen allows them to act as nucleophiles.
- B They react with carboxylic acids to form amides.
- C They form hydrogen bonds with water.
- D They accept protons from water molecules.

Your answer

[1]

57 Which row correctly shows the main products in electrolysis using graphite electrodes?

	Electrolyte	Product at the anode	Product at the cathode
A	MgBr ₂ (l)	bromine	magnesium
B	CuSO ₄ (aq)	oxygen	hydrogen
C	NaCl (aq)	chlorine	sodium
D	PbS(l)	hydrogen sulfide	lead

Your answer

[1]

58(a) Enzymes catalyse the breakdown of protein molecules in the digestive system. The tertiary structure of enzymes enables the substrate to bind to them.

State the meaning of the term tertiary structure of a protein.

-----[1]

(b) Give **two** ways a substrate can bind to an enzyme.

1 -----

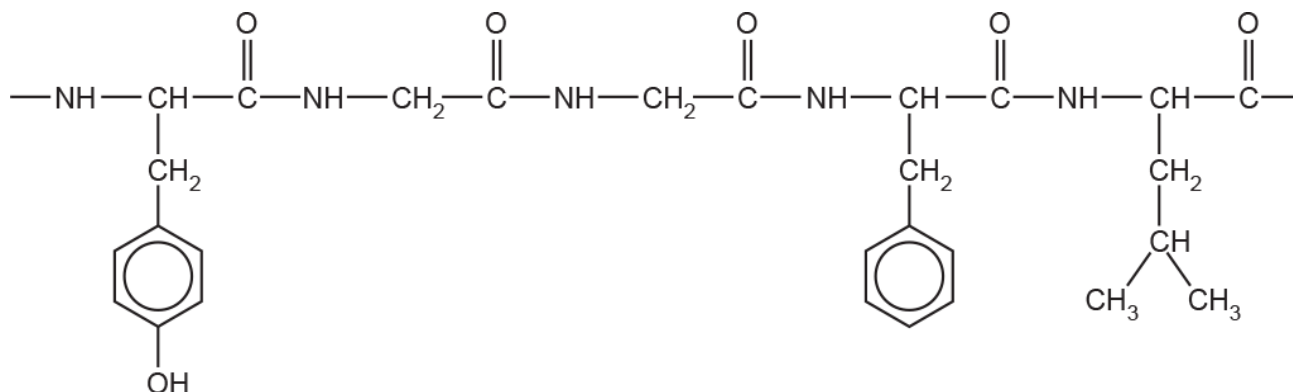
2 -----

[1]

- (c) Some students hydrolyse a protein in the laboratory by refluxing it with moderately concentrated hydrochloric acid.

(i) Circle **all** the chiral centres in the section of protein shown below.

[1]



(ii) Give the organic products of the complete hydrolysis of this protein section with hydrochloric acid.

[4]

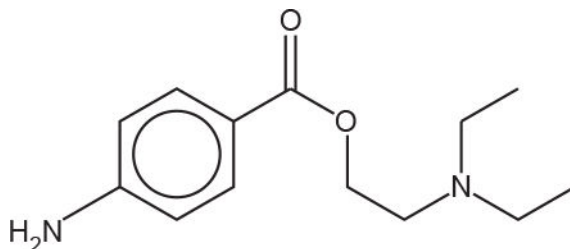
- (d) *The students use paper chromatography to confirm that the products of hydrolysis are those in part (ii) of the question above.

Describe how the students would **develop** and **analyse** the chromatogram to identify the products of hydrolysis.

You may include a diagram in your answer.

[6]

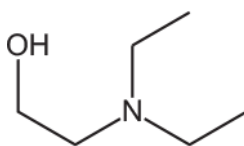
59(a) Procaine has been used as an anaesthetic in dentistry.



Procaine

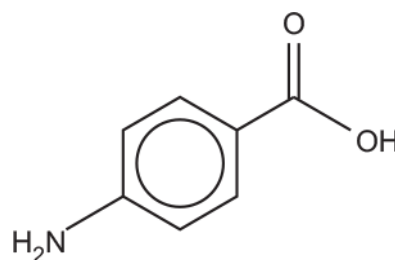
Some students reacted procaine with various reagents to see if they could make other useful substances from it.

They hydrolysed procaine, producing a solution containing compound **B** and the **sodium salt** of compound **C**.



compound B

liquid



compound C

solid

State at room temperature:

- (i) Suggest the reagent and conditions the students used for the hydrolysis.

----- [1]

- (ii) Suggest how the students could obtain a sample of compound **C** from the solution they obtained.

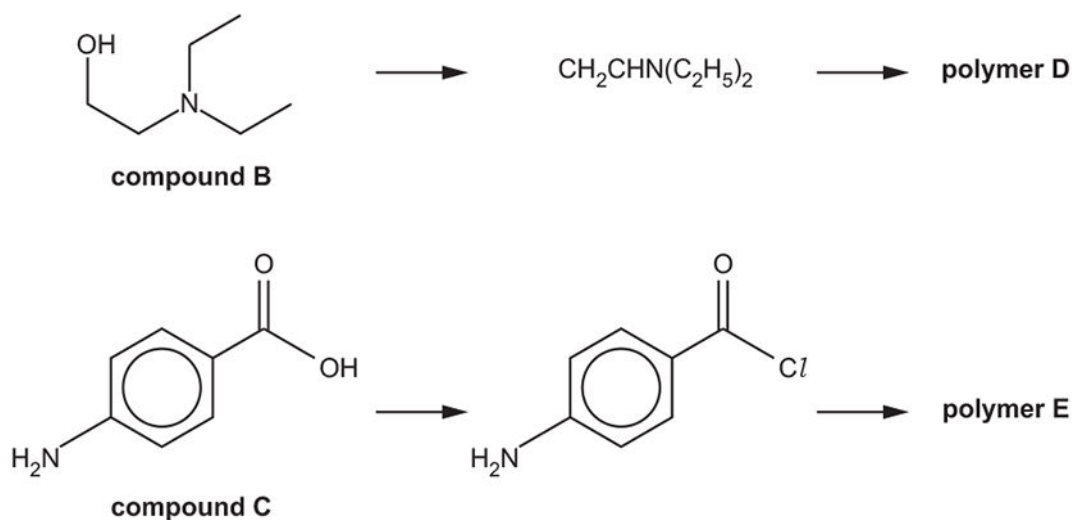
----- [2]

(iii) The students reacted procaine with ethanoyl chloride.

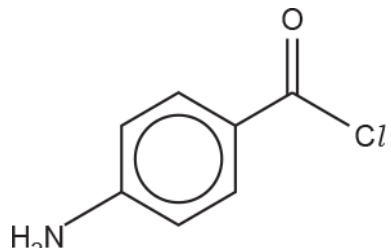
Give the formula of the organic product formed.

[1]

(b) Compounds B and C can be turned into monomers for polymerisation reactions.



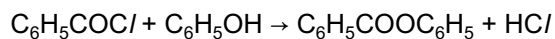
Give the structural formula for the repeat units of polymers D and E and give the **type** of polymerisation occurring in each case.

Monomer	Repeat unit of the polymer	Type of polymerisation
$\text{CH}_2\text{CHN}(\text{C}_2\text{H}_5)_2$	Polymer D	
	Polymer E	

[2]

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

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



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

[1]

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

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

(b)

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

Write the equation for this reaction.

[1]

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

----- [1]

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

----- [3]

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

----- [1]

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

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

----- [1]

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

Comment on the validity of this statement.

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

[4]

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

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

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

(i) Give the species responsible for these peaks

27

43

[2]

(ii) Propene has an isomer, cyclopropane.

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

.....

.....

.....

.....

.....

.....

[2]

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

Method 1

Reason:

.....

.....

Method 2 -----

Reason: -----

[4]

62(a) This question concerns the article The Strange Story of Napoleon's Wallpaper that is supplied as Insert for H433/02, June 2018.

One reason arsenic is poisonous because it reacts with –SH groups in amino acids.

Suggest how the removal of –SH groups might interfere with the way these amino acids form proteins.

----- [1]

(b) Arsenate(V) can replace phosphate(V) in nucleic acids.

Draw the skeletal formula of a DNA nucleotide containing thymine and with As instead of P.

[2]

(c) Write an equation for the reaction of a solution of As^{3+} with hydrogen sulfide. Show state symbols.

[2]

(d) A Marsh test is carried out for arsenic in a sample of As_2O_3 .

(i) Draw a labelled diagram of a suitable apparatus, showing the reactants and products.

[3]

(ii) Write equations for the formation and decomposition of arsine in the apparatus.

[2]

(e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$.

(i) Suggest a '*dot-and-cross*' diagram for the anion in Scheele's green.

[2]

(ii) State which part of Scheele's green is responsible for the green colour.

-----[1]

(f) State and explain the C–As–C bond angle in trimethylarsine.

[4]

(g) Summarise the evidence that Napoleon was killed by his wallpaper.

[3]

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

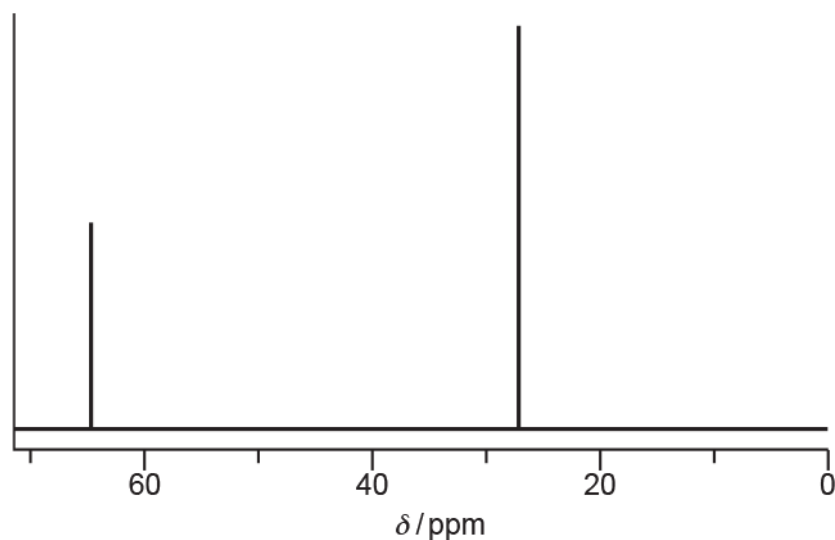


The propene produced in **equation 31.1** has many uses in the chemical industry.



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

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



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

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

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

Give the reagents and conditions to carry out this oxidation.

Reagents

Conditions

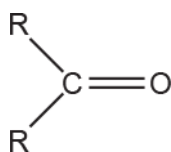
[1]

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

The formula of a carbonyl compound is shown below.

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

Name the type of reaction.

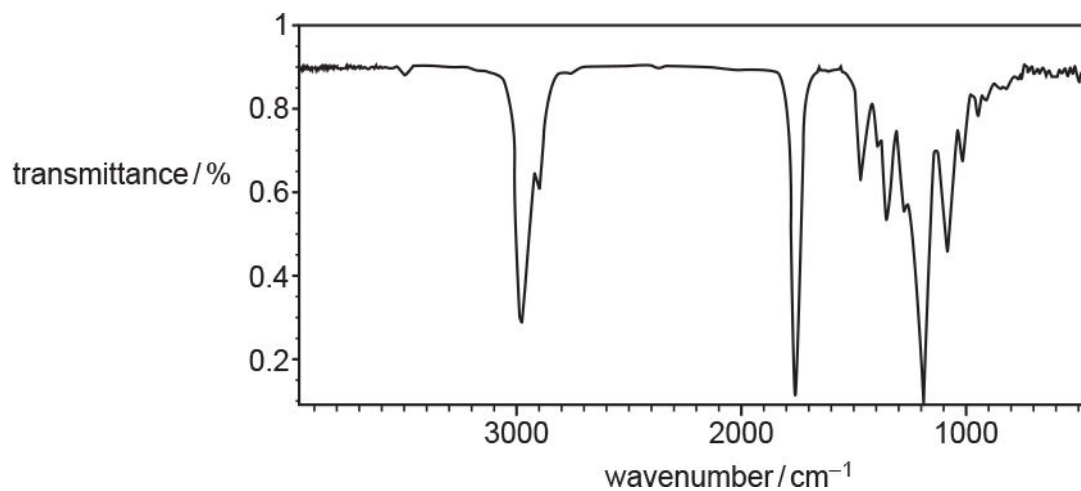


type of reaction [4]

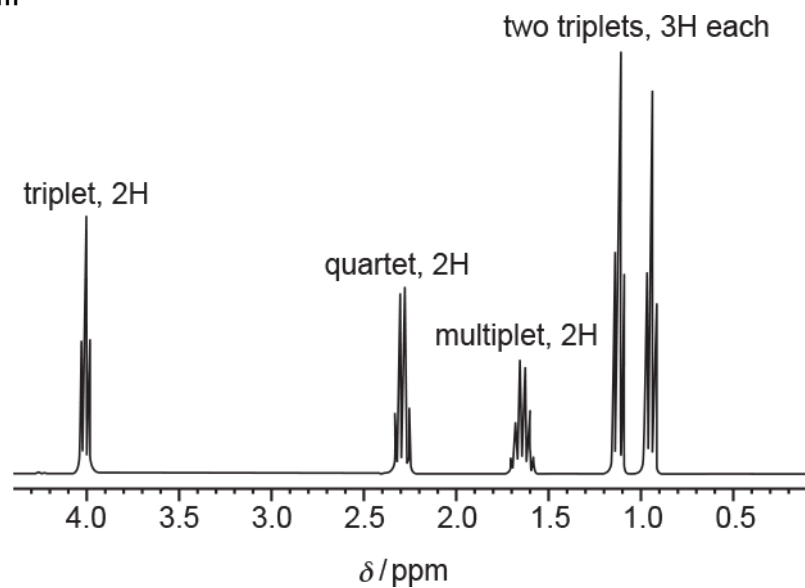
(d) *Compound A has six carbon atoms and can be made from propene using several steps.

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

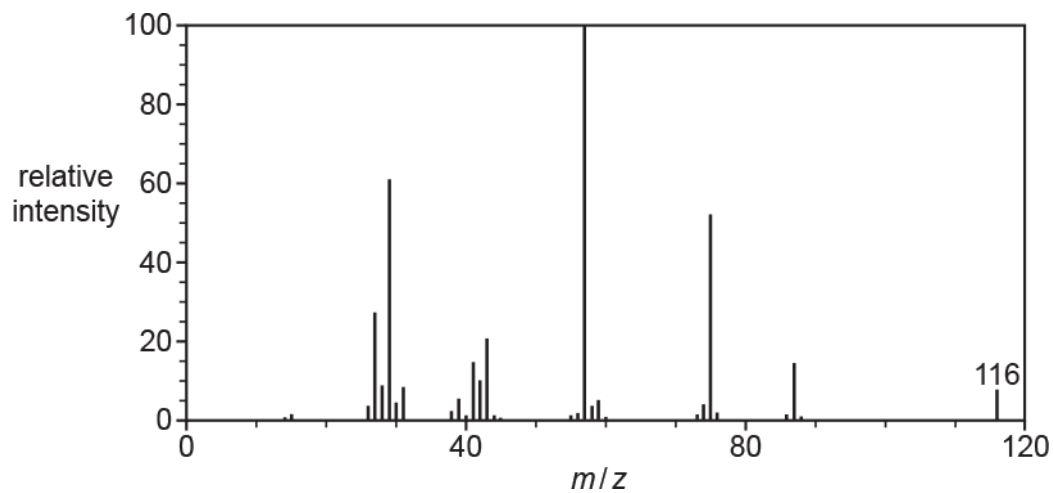
Infrared spectrum



Proton NMR spectrum



Mass spectrum



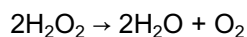
Use the information above to work out the structure of **compound A**.

Explain your reasoning, using evidence from each spectrum.

Structure of compound A

[6]

64(a) 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.

Catalase has an active site.

Explain how this results in faster decomposition of hydrogen peroxide.

----- **[3]**

- (b) *Some students are given a solution of catalase and solutions of hydrogen peroxide of different concentrations. They study the rate of reaction in **equation 3.1**.

They determine the relative initial rates of reaction at the different hydrogen peroxide concentrations, using the volume of oxygen produced.

Suggest the procedure they follow, including how the students should process their results. You may include a diagram as part of your answer.

[6]

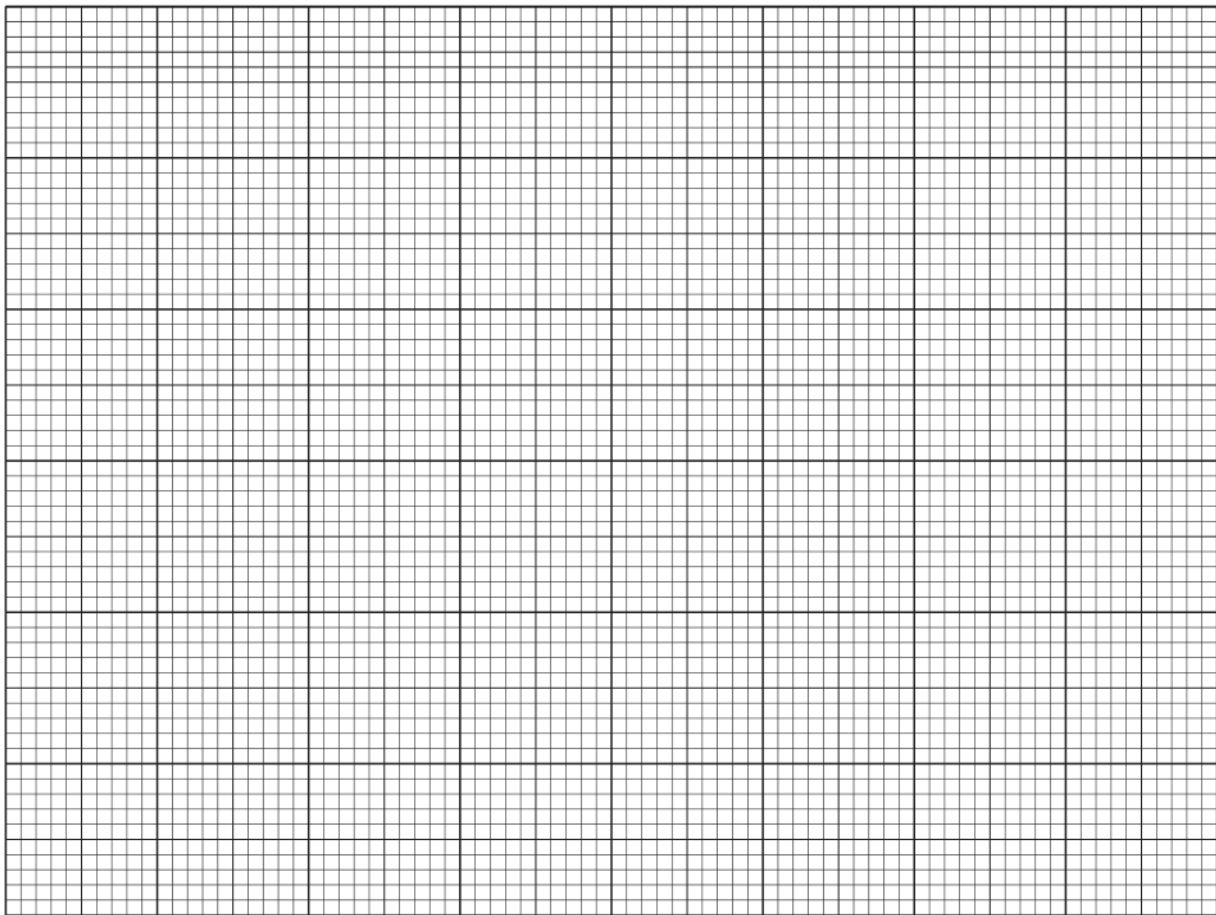
(c) The students record their results as shown in the box below.

Concentrations of hydrogen peroxide: 0.05 – 0.35 in 0.05 intervals.
Units of concentration mol dm ⁻³
Corresponding relative rates of reaction: 1.0; 2.1; 3.0; 3.8; 4.0; 4.1; 4.1
Temperature: 20 °C

(i) Arrange the results in a more appropriate format.

[2]

(ii) Use the grid below to plot a graph of the results and draw a line of best fit.



[4]

(d) A student says that the graph shows that the decomposition of hydrogen peroxide is first order with respect to both the hydrogen peroxide concentration and the catalase concentration.

- (i) Write the rate equation that would follow from the student's statement.
Give the units of the rate constant.

Rate equation:

Units of rate constant -----

[2]

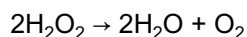
- (ii) Explain why the student is incorrect and give the correct information.

[3]

- (e) Hydrogen peroxide concentration is often measured as 'volume strength'.
1 cm³ of '1 volume' hydrogen peroxide produces 1 cm³ of oxygen at RTP.

Calculate the 'volume strength' of the 0.35 mol dm⁻³ hydrogen peroxide used by the students.

Equation 3.1



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

'volume strength' = ----- volume [3]

- (f) The students have 20.0 cm³ 0.35 mol dm⁻³ H₂O₂ and wish to make a 0.05 mol dm⁻³ solution.

How much water should they add?

volume of water to add = ----- cm³ [2]

65 Which reaction does **not** occur?

- A $\text{C}_6\text{H}_5\text{COOH} + \text{NaOH} \rightarrow \text{C}_6\text{H}_5\text{COONa} + \text{H}_2\text{O}$
- B $\text{C}_6\text{H}_5\text{OH} + \text{NaOH} \rightarrow \text{C}_6\text{H}_5\text{ONa} + \text{H}_2\text{O}$
- C $2\text{C}_6\text{H}_5\text{COOH} + \text{CaCO}_3 \rightarrow (\text{C}_6\text{H}_5\text{COO})_2\text{Ca} + \text{CO}_2 + \text{H}_2\text{O}$
- D $2\text{C}_6\text{H}_5\text{OH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{C}_6\text{H}_5\text{ONa} + \text{CO}_2 + \text{H}_2\text{O}$

Your answer

[1]

66 Which statement(s) is/are correct about the active site of an enzyme?

- 1 It is formed by the tertiary structure of a protein.
- 2 It changes shape at high temperature.
- 3 It has the same shape as the substrate.

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

Your answer

☐

[1]

67 Which statement(s) is/are correct about amino acids?

- 1 They all have a chiral centre.
- 2 They form buffer solutions in aqueous solution.
- 3 They form crystalline solids.

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

Your answer

☐

[1]

68(a) DNA carries the instructions for synthesising the primary structures of protein molecules.

Its backbone consists of alternating phosphate and deoxyribose sugar units. Bases are attached to the sugar units.

Use the RA H033 and H433 Data Sheet to draw a section of DNA.

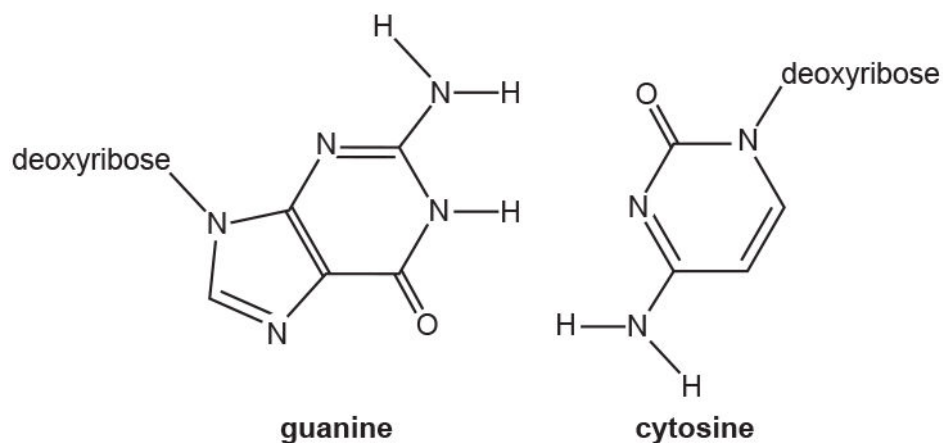
The section of DNA must consist of two phosphate units, one deoxyribose sugar unit and one thymine unit, all joined by condensation reactions.

[3]

(b) The double helix of DNA is formed by the bases pairing using hydrogen bonds.

Complete the diagram to show all the hydrogen bonds between guanine and cytosine.

Show the relevant lone pairs and partial charges.



[3]

- (c) The sequence of bases in DNA determines the primary structure of the protein synthesised.

Draw the structural formula for a section of a protein molecule formed from one each of the amino acids shown in Fig. 32.1.

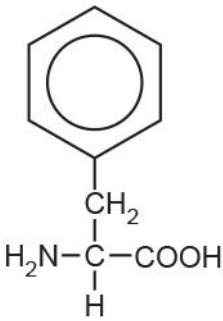
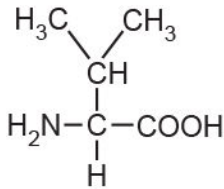
Phenylalanine	Valine
	

Fig. 32.1

[2]

(d) * An HIV protease enzyme acts on the protein substrate shown in Fig. 32.2.

Protein substrate

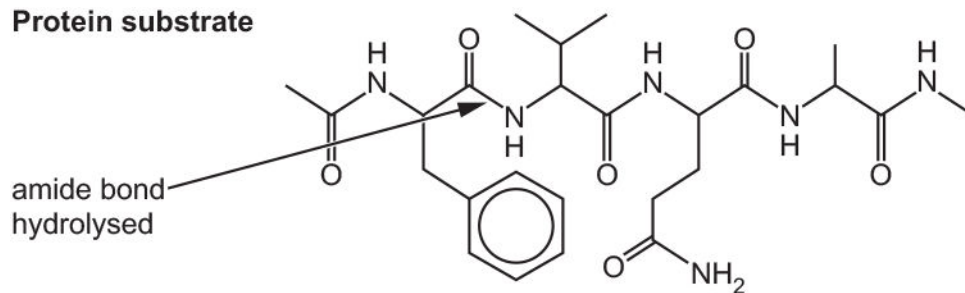


Fig. 32.2

The substrate in Fig. 32.3 acts as an inhibitor to the HIV protease enzyme.

HIV protease inhibitor

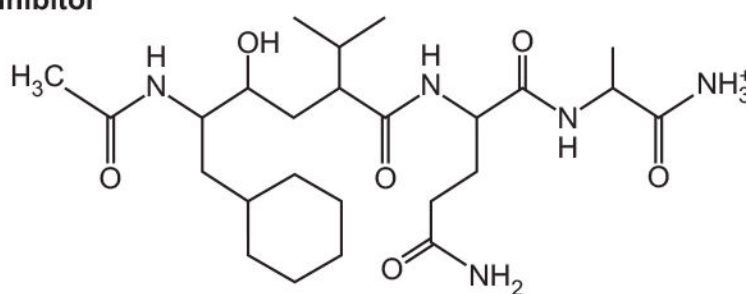


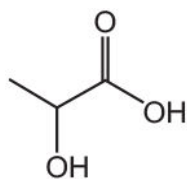
Fig. 32.3

Explain how an enzyme works and suggest how the HIV protease inhibitor affects the function of the protease enzyme.

Blank lined paper for writing.

69(a) A student taking A level chemistry and biology was researching the use of polymers in medicine. These are sometimes called biopolymers.

The student found that one of the most frequently used biopolymers is polylactic acid, PLA.
PLA is made from lactic acid.



Lactic acid

Lactic acid is a chiral molecule.

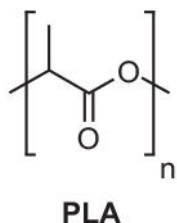
Explain the term **chiral** in this context and use 3-D structures to help your explanation.

Explanation

Structures

[3]

(b) The structure of PLA is shown below



PLA has a wide variety of uses. One use is in biodegradable medical devices (e.g. screws and plates that are expected to biodegrade within 6–12 months).

(i) Name the functional group in PLA and suggest the **type** of reaction that occurs when PLA biodegrades.

----- [2]

(ii) State the strongest type of intermolecular bonding that occurs between PLA polymer chains.

Explain, in terms of electronegativity, how this intermolecular bonding arises.

----- [2]

(c) The industrial manufacture of PLA uses heterogeneous catalysts.

A simple model of heterogeneous catalysis has four steps.

Describe the four steps involved.

1

2

3

4

[2]

70(a) TwaronTM is a polymer used to make body armour.

The polymer strands are made using the reaction in Fig. 1.1.

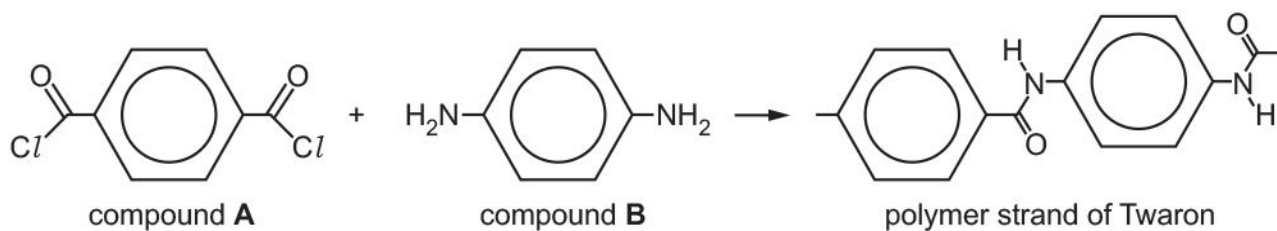


Fig. 1.1

Name the functional groups in compounds A and B.

A

B

[2]

(b) A Twaron polymer strand is hydrolysed.

(i) State the conditions that could be used to hydrolyse the polymer.

..... [1]

(ii) Draw the formulae of the **two** organic products of hydrolysis in the boxes.

--	--

[2]

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

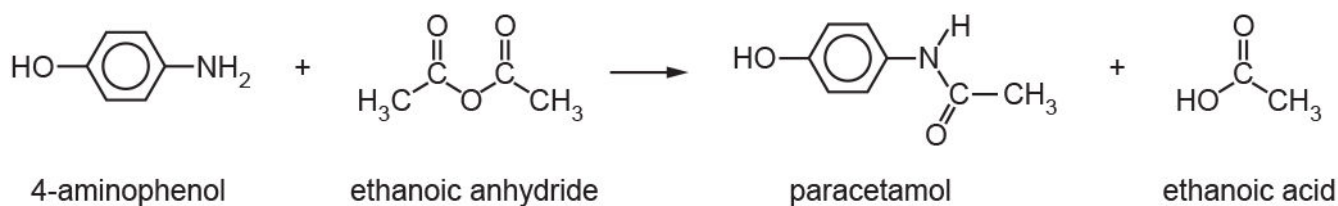


Fig. 2.1

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

- 1 _____
- 2 _____

[2]

- 72 Which statement about an enzyme reaction is correct?

- A Enzymes only work over a narrow range of pH values.
- B Enzymes only work over a 10 °C range of temperature.
- C The reaction is always zero order with respect to the enzyme.
- D The reaction is always zero order with respect to the substrate.

Your answer

☐

[1]

- 73 Insulin is a protein consisting of two chains. Parts of both chains are helical. The two chains are held together by covalent bonds.

Which statement about insulin is correct?

- A The covalent bonds holding the chains together are –S–S– bonds.
- B The overall folding of the helical parts and the other parts of the molecule is called its secondary structure.
- C The helical parts are held in shape by peptide links.
- D The helical parts are the primary structure.

Your answer

☐

[1]

74 Which esterification reaction is correct?

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

Your answer

[1]

75 Which formula has the correct systematic name?

	Formula	Name
A	$\text{C}_2\text{H}_5\text{COC}l$	propyl chloride
B	$\text{HOCH}_2\text{CH}_2\text{OH}$	ethylene glycol
C	$\text{CH}_3\text{CH}_2\text{CHO}$	propan-1-al
D	$(\text{CH}_3\text{CH}_2\text{CO})_2\text{O}$	propanoic anhydride

Your answer

[1]

76 CO and N₂ both have M_r values of 28.

What is the reason that CO and N₂ can be distinguished by **high-resolution** mass spectrometry?

- A CO has a dipole, unlike N₂.
B CO is more reactive than N₂.
C The values of their M^+ peaks would be different.
D CO is less reactive than N₂.

Your answer

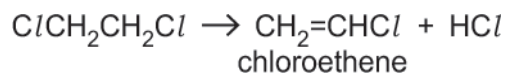
[1]

77(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 .



Give the **repeat unit** of poly(chloroethene) and the **type of polymerisation** taking place when it is formed from chloroethene.

Repeat unit	Type of polymerisation
	

[2]

(b) 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.

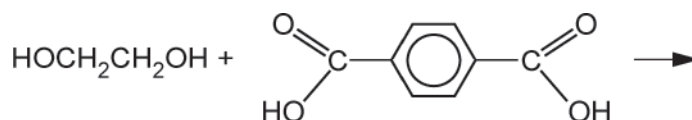
Name the mechanism for this reaction.

----- [1]

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

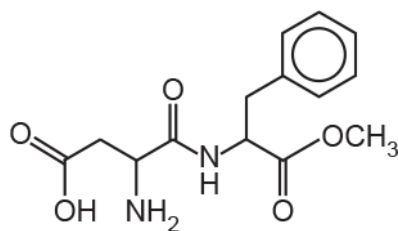
Complete the equation for the reaction below.

Show one repeat unit of the polymer.



[2]

78(a) Aspartame is a dipeptide that is used as an artificial sweetener. The structure of aspartame is shown in Fig. 1.1.



aspartame

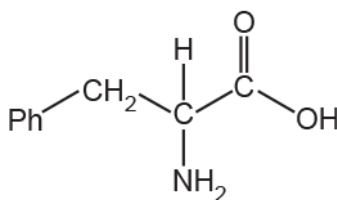
Fig. 1.1

Circle a secondary amide group on the structure of aspartame in Fig. 1.1.

[1]

(b) Aspartame is hydrolysed by boiling with acid. One of the products is phenylalanine which is shown in Fig. 1.2.

'Ph' represents a benzene ring.



phenylalanine

Fig. 1.2

(i) Phenylalanine has a chiral centre. Draw the three dimensional formulae to show the enantiomers of phenylalanine.



[2]

(ii) Phenylalanine in solution exists mainly as a zwitterion.

Complete the diagram in Fig. 1.3 to show the structure of this zwitterion.

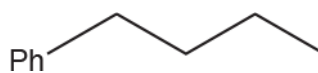


Fig. 1.3

[1]

(iii) A student says that acid hydrolysis of aspartame will only produce phenylalanine and one other amino acid.

Comment on the accuracy of this statement, giving the structures of any compounds you include in your answer.

[3]

(c) The enzyme pepsin catalyses the hydrolysis of protein chains. Some students read that pepsin breaks the peptide bonds adjacent to aromatic amino-acids, for example phenylalanine. This is because the active site is specific to benzene rings.

Suggest the type of bonds that form between a benzene ring and the active site.

[1]

(d) The students mix excess aspartame and pepsin in aqueous solution at room temperature. After 30 minutes they place a spot of the mixture on some chromatography paper.

(i) Describe the rest of their method, including how they could tell whether hydrolysis has occurred.

You may include a diagram in your answer.

[4]

(ii) Other students boil the mixture of aspartame and pepsin to attempt to speed up the hydrolysis reaction.

State and explain whether or not this would work.

[1]

- (iii) Another student says that using a higher concentration of aspartame at room temperature will speed up the hydrolysis reaction.

Comment on this statement.

----- [2]

- 79 Fig. 5.1 is a diagram from page 3 of the article. It shows a possible way in which a compound derived from cisplatin is thought to attach to a base in DNA. Two bonds have been labelled **B** and **C**.

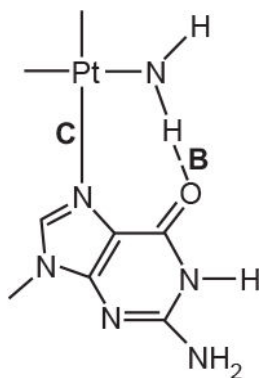


Fig. 5.1

- (i) What is the name of the base in Fig. 5.1? Use the Data Sheet to help you.

----- [1]

- (ii) What is the name of the type of bond at **B** in Fig. 5.1?

----- [1]

- (iii) Name the type of bond at **C** in Fig. 5.1 and describe how it is formed.

----- [2]

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

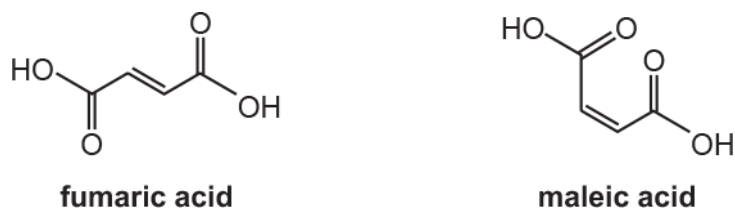


Fig. 4.1

- (i) Describe chemical tests that can be carried out in a laboratory to identify the two functional groups in both acids.

----- [2]

- (ii) A solution has 2.32 g dm^{-3} of maleic acid.

Calculate the volume (in cm^3) of 2.0 mol dm^{-3} NaOH(aq) that would completely neutralise 250 cm^3 of the solution.

volume = ... cm^3 [3]

(b)

(i) Give the **empirical** formula of both acids.

[1]

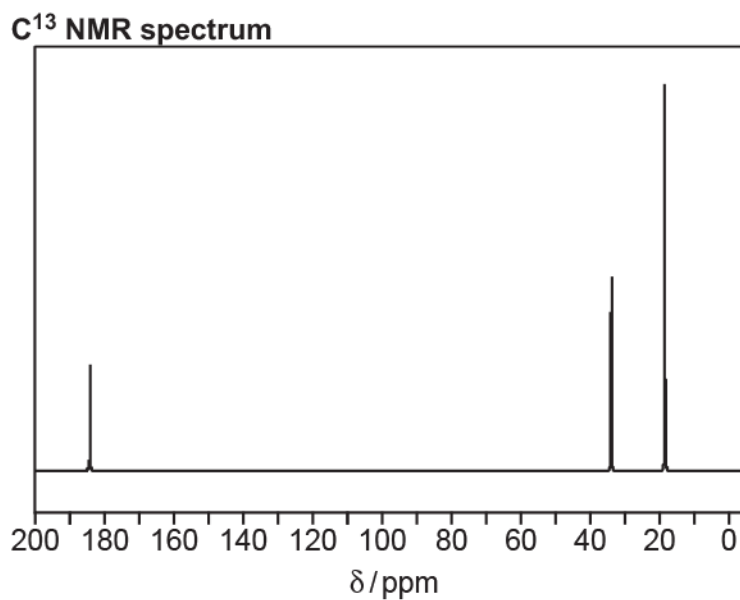
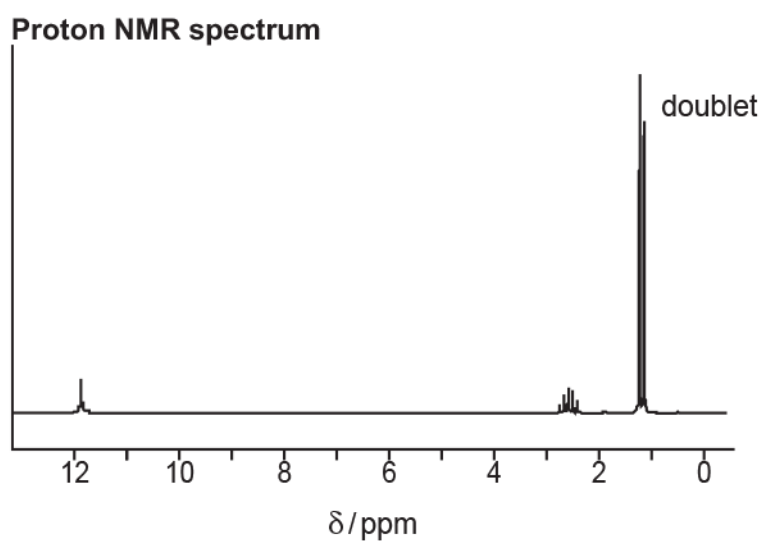
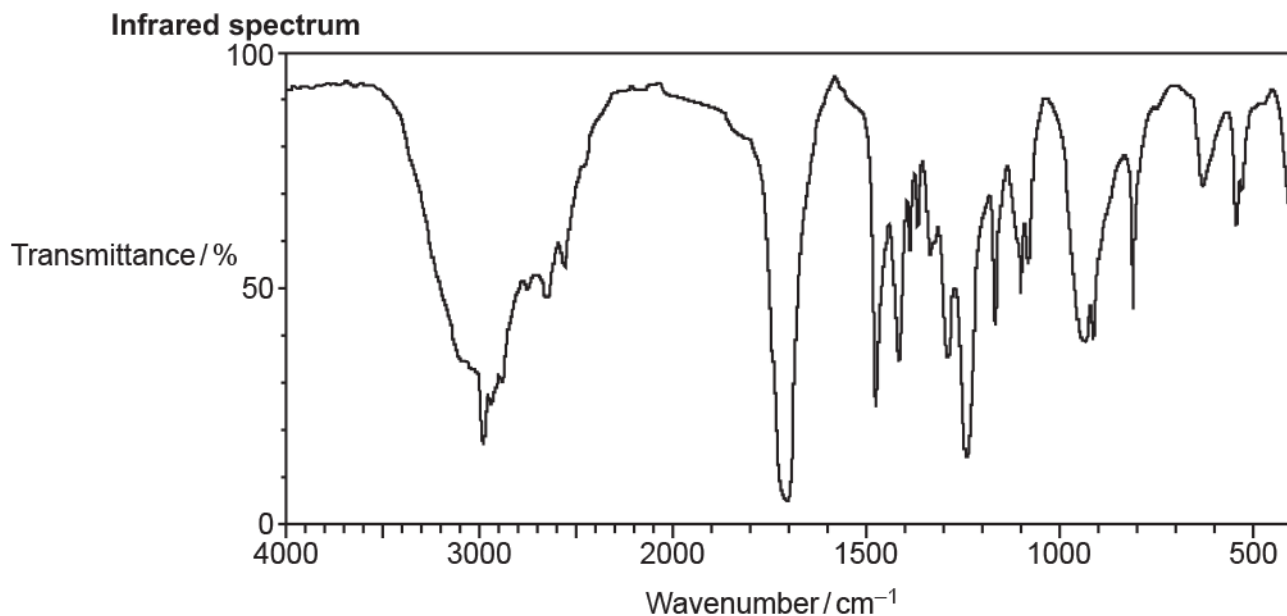
(ii) Give the systematic name for **maleic acid**.

[2]

(c) The mass spectra of maleic and fumaric acid both have a peak at 71. Suggest a reason for this.

[1]

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



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

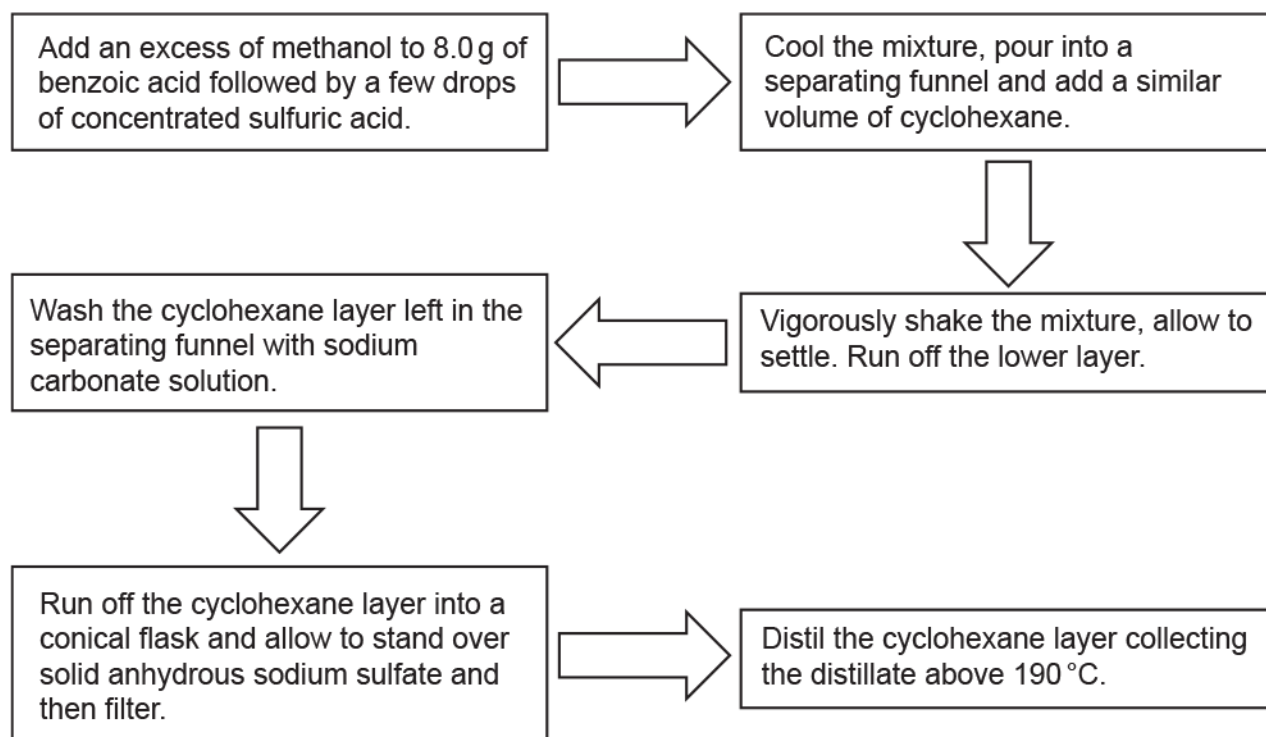
Compound **A** has four carbon atoms in its molecule.

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

[6]

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

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



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

(i) adding cyclohexane

----- [1]

(ii) adding sodium carbonate solution

----- [1]

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

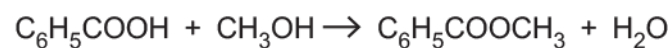
----- [1]

(iv) collecting the distillate above 190 °C

----- [1]

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

The equation for the preparation is:



benzoic acid methanol methyl benzoate

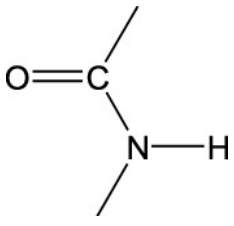
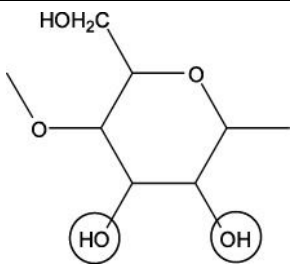
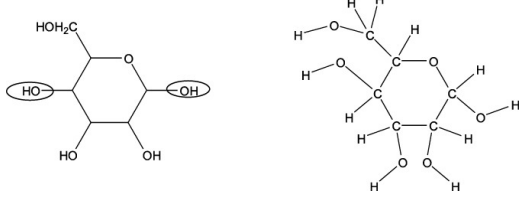
Calculate the percentage yield of methyl benzoate.

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

percentage yield = ... % [4]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	addition elimination ✓	1	ALLOW circles instead of underlining Examiner's Comments This was answered poorly with very few managing to pick both words. Many had elimination but usually paired it with neutralisation or substitution.
		ii	 ✓	1	IGNORE additions to this linkage, but bonds must be shown on C and N. Examiner's Comments This part was almost uniformly well done although it was often complicated by drawing the whole structure. Perhaps the common error was to miss the bond between the N and H atoms
			Total	2	
2	a	i	ether ✓	1	Examiner's Comments This was well answered, though some circled the primary alcohol or just the C to which a secondary hydroxyl was attached.
		ii	 either or both circled as above ✓	1	ALLOW if adjacent C is also circled Examiner's Comments This was well answered, though some circled the primary alcohol or just the C to which a secondary hydroxyl was attached.
		iii	 both circled OH groups present ✓ full structural formula correct ✓	2	Examiner's Comments Many gave the skeletal formula in (iii) rather than full structural, whilst those who attempted the full structure omitted one or more H atoms from the ring and usually drew -OH instead of -O-H.

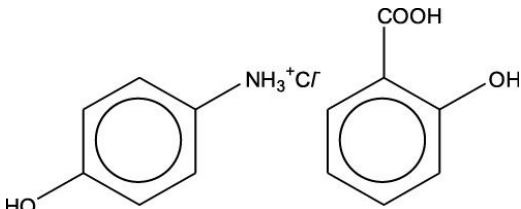
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	ethanoic acid ✓	1	Examiner's Comments The 'choking vapours' were identified correctly by many. However an equal number suggested they were an oxide of carbon, not realising they do not cause choking, just death if in sufficient amounts.
		ii	cellulose triethanoate: instantaneous dipole-induced dipole & permanent dipole-permanent dipole polyester: instantaneous dipole-induced dipole & permanent dipole-permanent dipole marking: instantaneous dipole-induced dipole in both polymers ✓ permanent dipole-permanent dipole in both polymers ✓	2	ALLOW van der Waals for instantaneous dipole-induced dipole DO NOT ALLOW abbreviations DO NOT ALLOW instantaneous-induced dipole forces unless they have used instantaneous dipole-induced dipole once ALSO applies to permanent dipoles hydrogen bonding is a CON so does not gain pd-pd mark Examiner's Comments This was not well answered; many had hydrogen bonding involved in at least one of the compounds with some sloppiness with abbreviations being used; 'instantaneous-induced dipoles' was frequently seen.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	longer chains / length of chains ✓ more intermolecular bonds / forces in longer chains ORA ✓ OR polymer molecules / chains closer ✓ intermolecular bonds stronger ✓ ORA OR shorter monomer chains ✓ more intermolecular bonds between polymer chains / intermolecular bonds more frequent along polymer chains ✓	2	NOTE amount of imb / fs per unit length will get 1 mark, needs to relate 'more' to 'stronger' for 2nd mark NOT how closely, more imbs may be inferred: linkages closer together IGNORE references to branch / side groups, crystallinity and any other factors Examiner's Comments The difficulty in this part was in relating, for example, length of polymer chain with number of intermolecular bonds. Many used ideas of crystallinity and side-chains without making any real headway
			Total	9	

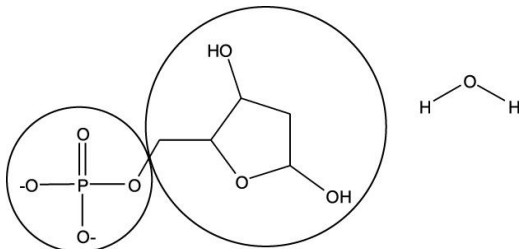
Mark Scheme

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

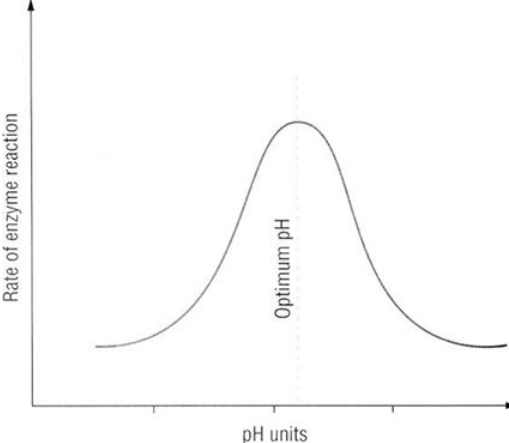
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	draw pencil-line near bottom of plate / sheet ✓ place 1 drop (or similar word) of mixture AND a drop of each of the 2 compounds (on the line) AW ✓ place plate in solvent, line above solvent level AND add lid / cover ✓ when solvent nears top of plate AW, remove / dry plate ✓ locate spots with / expose to UV light / iodine ✓ compare heights / position of spots from mixture with the two compounds AW OR calculate / measure / determine R_f values of spots and compare with those of the two compounds AW ✓	6	please annotate marks given with ticks ALL marking points may be gained from labelled diagram(s) ‘near bottom’ may be implied by what follows DO NOT ALLOW paper for plate / sheet BUT ecf for further use ALLOW draw base-line with pencil any other named locating agent is a CON DO NOT ALLOW ‘locating agent’ alone DO NOT ALLOW vague statements about comparing spots, MUST refer to positions DO NOT ALLOW vague statements about R_f values <i>e.g.</i> R_f values will identify compounds MUST indicate that spot heights or R_f values have been measured AND compared Examiner's Comments The students who had worked hard on their revision did very well here with many gaining full marks. Some ninhydrins but not many, some used chromatography paper, others only spotted the mixture on to the plate and a few lost the last mark for not measuring and comparing R_f values.
			Total	8	

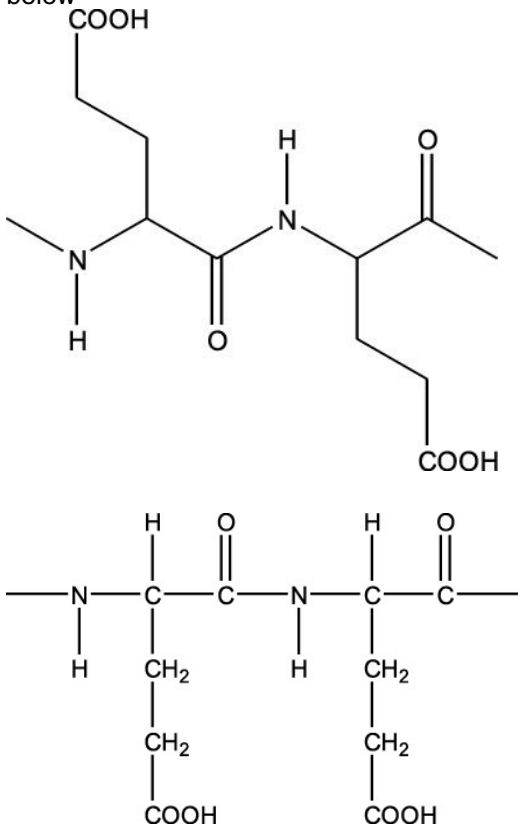
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	nucleotide ✓	1	IGNORE any details of the constituents of nucleotides
		ii	 phosphate structure (circled) correct ✓ deoxyribose structure (circled) correct ✓ water structure ✓	3	ALLOW an OH group for an O⁻ on phosphate The phosphate MUST be joined at the primary OH ALLOW H₂O or any bond angle for water Examiner's Comments Nucleotide was well known in (i) but in drawing the structural formulae in (ii) the phosphate was often joined to the wrong hydroxyl group with other hydroxyl groups added to the ribose structure.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	base pairs held together by hydrogen bonding / bonds ✓ adenine-thymine 2 hydrogen bonds AND guanine-cytosine 3 hydrogen bonds ✓ hydrogen bonds between base pairs break ✓ (two single) helices / strands are formed ✓ each base (on these helices / strands) forms hydrogen bonds to a new (correct / complementary) base AW ✓  to gain this last point replication must be linked to breaking AND forming hydrogen bonds	5	May be implied by stating the number of hydrogen bonds in each case different numbers of H bonds is NGE May refer to just one strand IGNORE references to phosphodiester bonds <i>i.e.</i> both forming and breaking H bonds have to be mentioned in the answer Examiner's Comments A number of the best candidates gained full marks here and were able to produce clear concise well thought out answers. However, some had rote-learned and produced a response without really thinking about whether it answered the question. This was particularly so if they had a biological background where the role of m-RNA was often discussed at length
c	 Rate of enzyme reaction pH units Optimum pH curve correct shape ✓ label for optimum pH in line with fastest rate of reaction ✓	2	ALLOW any curve with a peak, not necessary to be symmetrical Optimum pH should indicate the peak of graph AND be labelled as such Examiner's Comments Generally fine, but some strange curves and many did not label the optimum pH or just indicated pH7.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	structure correct - 2 examples shown below  ✓	1	ALLOW any correct structure ALLOW without 'spare bonds' ALLOW dipeptide structure which must have its secondary amide / peptide between two chiral C atoms Examiner's Comments Drawing the protein chain caused many problems; candidates often giving the same answer as in part b or linking to the wrong side chain and / or using an ester linkage.
		ii	((side) -COOH / carboxyl groups will (lose protons and)) form -COO⁻/carboxylate ions ✓	1	also forming NH₂⁺ / NH₃⁺ is a CON ALLOW carboxyl / COOH becomes deprotonated AW Examiner's Comments In the last part, many did not appear to understand the phrase 'increasing the pH' and went on to discuss protonation of the amino group. A significant number just gave generalisations about ionisation within the molecule.
			Total	13	

Mark Scheme

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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6	a	i	ethanol ✓	1	NOT ethan-1-ol Examiner's Comments The name 'ethanol' was given by most candidates, though some described it as 'ethan-1-ol', which was not accepted.
		ii	propane – 1,2,3 – triol ✓	1	ALLOW errors in gaps, commas and dashes ALLOW propan – 1,2,3 – triol IGNORE glycerol / glycerine Examiner's Comments Again, many candidates knew 'propane – 1,2,3 – triol', though many benefited from the lack of insistence on the 'e'.
	b	i	$\text{C}_2\text{H}_5\text{CH}(\text{CH}_3)\text{COOH}$ structure ✓ chiral C marked on correctly bonded structure ✓	2	ALLOW any unambiguous indication of structure and any clear way of indicating chiral carbon (eg asterisk) Examiner's Comments Many candidates could draw the structure of the acid and, of those, almost all correctly circled the chiral centre.
		ii	No broad peak at 2500 – 3200 OR no O-H peak in range 2500 – 3200 OR no peak 1700 – 1725 (for acid C=O) ✓ For ester C=O: EITHER Peak at 1741 OR peak in range 1735 – 1750 ✓	2	ALLOW 'around / at 3000' for '2500 – 3200' to score this way it must be stated that there is no peak peak value, 'ester' and bond necessary for this mark IGNORE extra information even if wrong. Examiner's Comments Most candidates could give one of two answers 'no peak at 1700 – 1725' or 'no broad peak at 2500 – 3200' and gave them in the required detail to score the mark for the absence of an acid. They could usually also write that there was a peak between 1735 and 1750 that was given by the C=O of an ester.

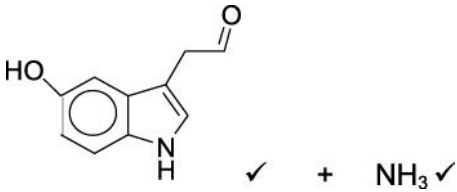
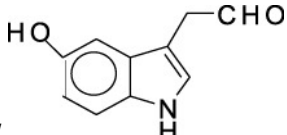
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	1. structure: $\text{CH}_3\text{COOCH}(\text{CH}_3)_2$ ✓✓ $(\text{CH}_3)_2\text{CHCOOCH}_3$ ✓ 2. description of doublet (1.2): one H on adjacent carbon ✓ <i>Maximum of 2 from</i> 3. 3 proton environments / protons in ratio 6:3:1 (or 1:3:6 etc) 4. two CH_3 groups on one C / two CH_3 in same environment ✓ 5. CH attached to O / CH-O / O-CH (5.0) OR CH next to carbon(s) with many / six H (5.0) ✓ 6. CH_3 attached to C=O (2.0) OR CHC=O OR CH_3 next to carbon with no H ✓	5	ALLOW any unambiguous representation of the structure ALLOW 'H' for 'proton' but IGNORE H^+ 5. NOT CHO 6. IGNORE CO for C=O IGNORE any incorrect points unless they directly contradict one that has been awarded a mark Examiner's Comments Some candidates scored well here, giving the correct ester, describing why a doublet was formed and giving two other relevant reasons. Other candidates got the right answer but failed to back it up with good reasoning, which had to be expressed in recognised chemical terms. For example, candidates were better at describing splitting in terms of the 'number of protons on the adjacent carbon' but vaguer statements such as 'one proton in the neighbouring environment' did not score. Some credit was give for the ester 'the wrong way round', though the 3H at 2.0 gave the clue that it was an ester of ethanoic acid, not methyl propanoic acid. A counting exercise on the atoms would have revealed that there was no C=C bond. Some candidates thought that the 6H peak was caused by two CH_3 groups on different parts of the molecule.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7		i	(primary) amide ✓	1	'secondary' is CON Examiner's Comments Most could name the amide group. Some wrongly named it 'secondary amide' or 'peptide'
		ii	$2 \text{ RCONH}_2 + \text{H}_2\text{SO}_4 + 2\text{H}_2\text{O} \rightarrow (\text{NH}_4)_2\text{SO}_4 + 2 \text{ RCOOH}$ species ✓ balancing with correct species ✓	2	IGNORE state symbols ALLOW multiples and halves Examiner's Comments Many could write the equation for the formation of ammonium sulfate and the carboxylic acid and balance it.
		iii	hydrolysis ✓	1	ALLOW any unambiguous identification of the word Examiner's Comments Most chose the correct answer, 'hydrolysis', though a few chose 'substitution'.
			Total	4	

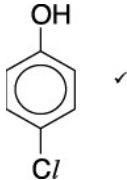
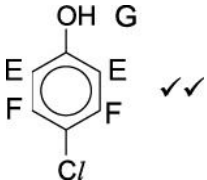
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8	a			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.
	b		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.
			Total	6	

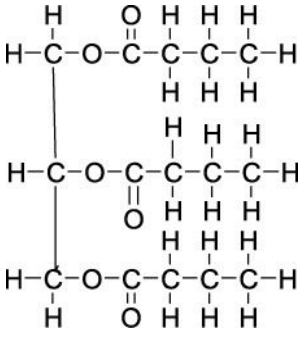
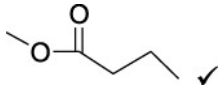
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9	a	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	
		iv	addition (polymerisation) since C=C / carbon-carbon double bond / alkene double bond / unsaturated ✓ <pre> H H - C - H H - C - C - H C=O O H - C - H H ✓ </pre>	2	both points needed to score first mark ALLOW 'CH ₃ ' 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	three proton / H / hydrogen environments	1	IGNORE 'H⁺' Examiner's Comments This question showed a reasonable understanding of nmr spectroscopy. Almost all got part (i) correct.
		ii		1	ALLOW hydrogen atoms shown on ring (for part (iii)) Examiner's Comments Fewer were able to identify the correct isomer compared to (i). Of those who did, some then failed to point out <i>both</i> the protons causing peaks E and F.
		iii	 one mark for labelling G one mark for labelling E and F (which can be reversed)	2	If e(ii) is an incorrect isomer, award one mark for G if it labels the OH hydrogen E and F must be indicated on both sides to score second mark.
		iv	Protons are attached to a carbon atom where... OR the proton environment has... ...the adjacent carbon with one proton ✓	1	must imply 'adjacent' eg 'neighbouring' etc and mention both carbons (unless 'proton environment' replaces the first carbon) and both protons. ALLOW hydrogen / H (not H⁺) for 'proton' Examiner's Comments Some candidates correctly described the protons responsible for the peaks as being on a carbon with an adjacent carbon with one hydrogen. The commonest error was to say 'they' instead of 'protons' which did not quite answer the question, referring to the peaks rather than the protons.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	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		1	OR other way round bond angles can vary Examiner's Comments Was well done with most candidates being able to draw the structures and many to predict boiling points in terms of intermolecular bonds.
		ii	CH₃CH₂CH₂COC/ ✓	1	ALLOW any correct structural or skeletal formula or mixture IGNORE C₃H₇COC/ (chain could be branched) Examiner's Comments Was well done with most candidates being able to draw the structures and many to predict boiling points in terms of intermolecular bonds.

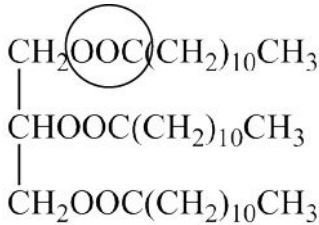
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	permanent (dipole)—permanent dipole AND instantaneous (dipole)—induced dipole ✓ acid has hydrogen bonding ✓ more energy required to separate particles / break bonds in acid (ora) so ester has lower bpt (ora) ✓	3	type of imb must not be abbreviated or misspelled (QWC) 'hydrogen bonding' CONS first mark Examiner's Comments Was well done with most candidates being able to draw the structures. Many candidates realised that the intermolecular bonds in the ester were permanent dipole – permanent dipole and instantaneous dipole – induced dipole but several lost marks through wrong spelling of these terms. In some cases the spelling was hard to decipher and candidates with poor handwriting should at least try to do better in questions where the spelling of technical terms is a requirement.
			Total	8	
11			D	1	
			Total	1	
12			C	1	
			Total	1	
13			A	1	
			Total	1	
14			B	1	
			Total	1	
15			B	1	
			Total	1	
16			A	1	
			Total	1	
17			B	1	
			Total	1	

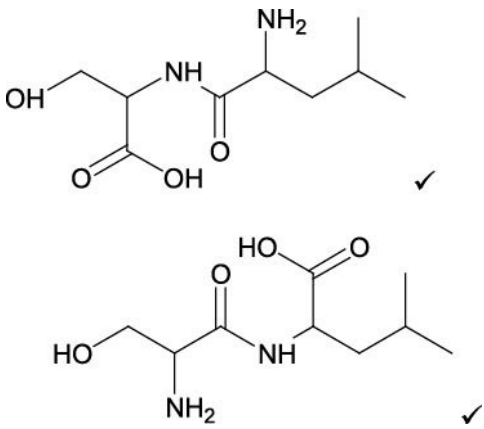
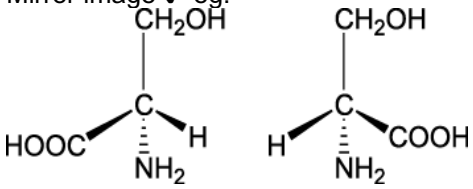
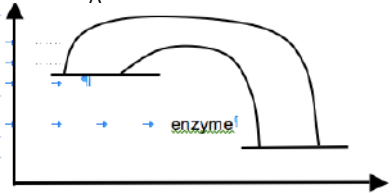
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
18	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) 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.		
	b		Substrate / reactant has specific shape ✓ Fits active site in enzyme ✓	2	
			Total	8	
19			 Any of the ester groups circled correctly ✓	1	IGNORE circled adjacent carbons
			Total	1	
20			(compound contains a) chiral C / chiral centre / asymmetric C ✓ (the enantiomers are) mirror images ✓	2	ALLOW 3-D sketch showing stereoisomers
			Total	2	
21			C	1	
			Total	1	
22			C	1	
			Total	1	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
23	a	Correct amide link in 1 structure ✓ Fully correct skeletal structures 1 each, eg: 	3	
	b	One correct 3d representation ✓ Mirror image ✓ eg: 	2	ALLOW  or  etc NOT 
	c	They have an active site ✓ Substrate binds to the active site and reacts with lower E_A ✓	2	
	d	Shapes of the 2 curves with enzyme one at lower E_A ✓ 	1	Activation enthalpies do not need to be labelled One line must be labelled 'enzyme' or 'no enzyme'
	e	Correctly plots points ✓ Line of best fit drawn ✓	2	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	f	<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) Learners fully analyse the scientific information shown on the graph concerning orders of reaction. They correctly evaluate the learners' comments and interpret them in terms of the correct chemistry. <i>The explanation is relevant and logically structured and contains no errors.</i> Level 2 (3–4 marks) Learners partially analyse the scientific information on the graph concerning orders of reaction AND they partially correct the learners' conclusion. OR they do one aspect fully and the other weakly. <i>The explanation is generally relevant and logically structured and contains few errors.</i> Level 1 (1–2 marks) Learners show some ability to analyse the graph or to correct the learners' conclusion <i>A partial explanation is attempted and has some structure.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: <i>Orders of reaction</i> - graph is a straight line / shows proportionality for low substrate concentrations - shows reaction is first order initially - then graph has zero slope / rate does not change as substrate conc increases - so zero order wrt substrate at high substrate conc - no conclusions can be drawn about order wrt enzyme as concentration is not changed <i>Rate determining steps</i> - mechanism is $E + S \rightarrow ES \rightarrow E + \text{products}$ - Rate determining step at low substrate concentration is $E + S \rightarrow ES$ - since this indicates first order - Explanation of ES - This is not the rate-determining step at high substrate concentration - Here it is $ES \rightarrow \text{products}$ or enzyme is saturated with substrate

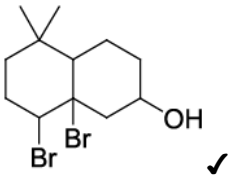
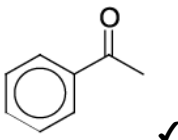
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	g		 Shape of graph: rises to peak, then falls ✓ Initially as temperature increases more collisions above E_A, so increasing rate ✓ then the kinetic energy breaks imbs in active site and it loses its specific shape and substrate can't bind. ✓	3	ALLOW enzyme becomes denatured
	h		Advantage: Allows faster reaction at lower temp / saves fuel ✓ Disadvantage: easily denatured / inhibited / sensitive to pH / difficult to recover after use. ✓	2	
			Total	21	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
24	<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) Candidate identifies the structure of the compound correctly, the evidence for this identification uses information from composition by mass AND IR spectrum AND proton NMR spectrum. <i>The identification is clear and logically structured. The evidence selected is relevant and fully supports the identification.</i> Level 2 (3–4 marks) Candidate identifies the compound as a keto-acid, the evidence for this identification uses information from composition by mass AND EITHER IR spectrum (both points) OR proton NMR spectrum OR using information from IR spectrum AND proton NMR spectrum. <i>The identification has a logical structure. The evidence selected is in the most-part relevant and supports the identification.</i> Level 1 (1–2 marks) Candidate makes an attempt at identifying the compound and the evidence to support this identification uses EITHER information from composition by mass OR IR spectrum OR proton NMR spectrum. <i>The identification is basic and communicated in an unstructured way. The evidence selected is limited and the relationship to the identification may not be clear.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Compound is $\text{CH}_3\text{COCH}_2\text{CH}_2\text{COOH}$ Composition by mass: $\text{C}_5\text{H}_8\text{O}_3$ calculated. IR spectrum: - COOH from IR at 3200-3600 (no OH at 3200-3600/3640). Proton NMR: (any 3) 4 proton environments - peak at 10.5 indicates COOH - peaks at 2.2-2.7 indicate (three) Cs next to (a single) C=O - singlet at 2.2 indicates C with no Hs on adjacent carbons AND triplets at 2.6 and 2.8 indicate Cs with one adjacent CH_2.
	Total	6	

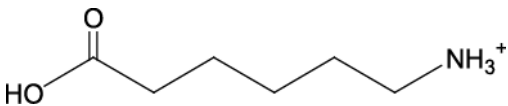
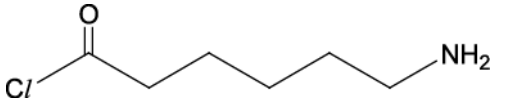
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25	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	
26	a	i	secondary amide	1	
		ii	six C atoms between functional groups / links AW	1	ALLOW 'six carbon atoms'
		iii	no water / small molecule produced ✓ addition ✓	2	
		iv	hydrogen bonding ✓ between NH and O/N ✓ stronger than pd-pd ✓ more energy to break ✓	4	For mpt 3, allow incorrect imb from (b)(ii)
	b	i	hydrochloric / sulfuric acid ✓ (heat under) reflux ✓	2	
		ii		1	ALLOW any unambiguous structure IGNORE anions
		iii	 ✓ acid / acyl chloride ✓	2	ALLOW any unambiguous structure For second mark ALLOW primary amine if carboxylic acid is shown on left of molecule.
			Total	13	
27			$2\text{RCONH}_2 + \text{H}_2\text{SO}_4 + 2\text{H}_2\text{O} \rightarrow 2\text{RCOOH} + (\text{NH}_4)_2\text{SO}_4$ species ✓ balancing with correct species ✓	2	IGNORE state symbols ALLOW multiples and halves
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28	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
29	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

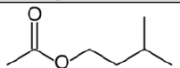
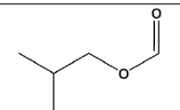
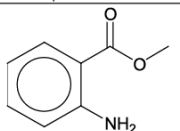
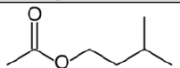
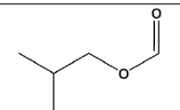
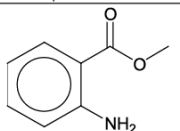
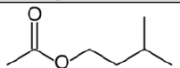
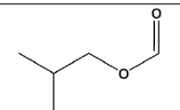
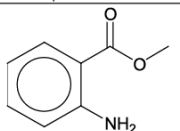
Mark Scheme

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

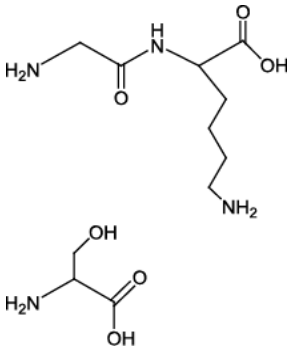
Mark Scheme

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

Mark Scheme

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

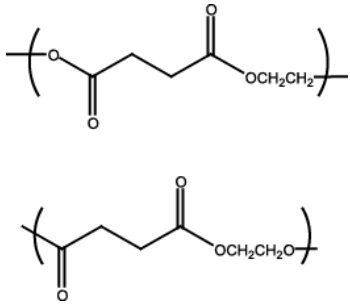
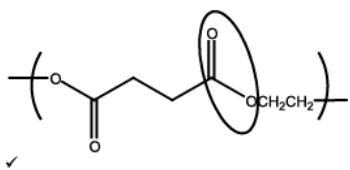
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32	a		secondary structure: the folding of the chains OR (forms) helices or sheets ✓ tertiary structure: further folding OR (final) 3D structure ✓	2	Examiner's Comments This was very well answered by most candidates.
	b		a hole / cleft / crevice / specific shape (in the enzyme structure) AW ✓ substrate/ protein binds / fits / bonds ✓ reaction/ hydrolysis occurs / substrate is broken down / conversion into products ✓	3	ALLOW part of protein tertiary structure ALLOW shape in enzyme which fits substrate ALLOW catalyse reaction between enzyme and substrate Examiner's Comments Most were able to follow on to discuss successfully the function of the 'active site' in an enzyme. These first two parts clearly gave candidates confidence to tackle the challenges ahead.
	c		 some hydrolysis at one or more amide links showing -COOH and -NH₂ on two different molecules ✓ idea of correct (right-hand) amide link only being hydrolysed ✓ completely correct ✓	3	accept any unambiguous structures Examiner's Comments Most could hydrolyse a secondary amide successfully although some unfortunately decided that ions, of varying types, would be produced. Many also hydrolysed both amide linkages, whilst others made simple errors in drawing the correct structures, notably missing the H off the remaining amide linkage.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	first part of graph first order for substrate - related to shape (e.g. 'graph shows proportional' / 'linear' / 'rate doubles as conc. doubles' / 'constant positive gradient' AW) ✓ rds is equation 1 / substrate is in rds ✓ second part of graph zero order for substrate ✓ rds is equation 2 (or no longer equation 1) / substrate no longer in rds ✓ all active sites (on enzyme) full/ saturated ✓	5	QWC – to score first mark, the statement of first order must be related to the shape / attributes of the graph may write reasoning on graph but just saying 1st order is insufficient for mark NOT just 'straight' Examiner's Comments Some excellent succinct answers showing clear understanding and using all the terms correctly and explaining in relatively few words, fitting the response easily into the space provided. The most frequently lost mark was the first for failing to explain with appropriate detail how the graph supported their conclusion that the initial rate was a first order process with respect to the substrate. The idea of rate determining step was often not referred to at all.
		ii	straight line (parallel to x-axis) at rate = 0 ✓ <u>active site</u> is destroyed / changes shape ✓	2	may draw a diagram ALLOW line along the x-axis IGNORE denatured Examiner's Comments Instead of 'describing the graph' as requested most tried to explain what happened to the rate of reaction, thus not many gained the first mark. Often 'denaturing' was used without any explanation in what way the 'natural' structure of the enzyme was altered.
			Total	15	

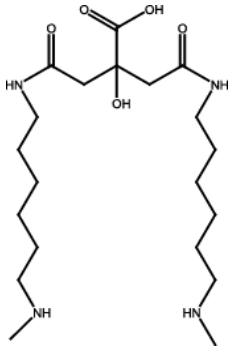
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a	i	either of the following structures ✓ 	1	ALLOW any correct structure using any skeletal and / or structural formulae conventions ALLOW without brackets BUT MUST have linking bonds Examiner's Comments All parts were mostly correct, although in (ii) 'esterification', 'ester' and 'copolymer' were not uncommon.
		ii	<u>polyester</u> ✓	1	IGNORE condensation
		iii		1	DO NOT ALLOW if C atoms are circled

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	imb / fs in polyesters: instantaneous (dipole)-induced dipole / Van-der-Waals AND permanent (dipole)-permanent dipole ✓ imb / fs in polyamides: instantaneous (dipole)-induced dipole AND permanent (dipole)-permanent dipole AND hydrogen bonds ✓ a <u>hydrogen</u> bond is stronger than the other correct imb / fs ✓ stronger bonds between chains / molecules (mean stronger fibres)✓	4	DO NOT ALLOW abbreviations nor shortened names (e.g. permanent dipole bonds for bond types) UNLESS the full names have been used first ALLOW abbreviations if full names given once ALLOW hydrogen bonds are the strongest ALLOW more energy needed to break bonds between chains Examiner's Comments A careful reading of the question was very important here and many candidates lost marks because they failed to spend enough time considering what was being asked of them. To this extent, not all of the IMBs were named in each polymer, often just the strongest. Precision in answers to these types of questions where a comparison is called for is most important. Too many candidates still think that polyesters possess hydrogen bonds. Also, there seems to be a perception that if a substance possesses hydrogen bonds then permanent dipole-permanent dipole bonds are absent.
		ii	stretching polymer AW ✓ causes chains to be aligned / lined up / makes polymer more crystalline ✓ chains are closer together so imb / fs stronger ✓	3	ALLOW 'pulled' DO NOT ALLOW stretching polymer chains IGNORE cooling NOT heating NOT more imb / fs IGNORE any references to 'energy' Examiner's Comments Exceptionally well done. Sometimes 'chains were stretched' resulting in 'more bonds'.
	c	i	1,6-diaminohexane ✓	1	ALLOW hexane-1,6-diamine IGNORE commas, dashes and gaps.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	 an amide group correct ✓ structure all correct ✓	2	ALLOW $\text{--NH(CH}_2\text{)}_6\text{NH}_2$ <i>i.e.</i> NH_2 at end of chain ALLOW --NH-- ALLOW correct structure formed by use of central --COOH (one of the side chains will lack a $\text{--CH}_2\text{--}$ before the amide group) Examiner's Comments Mostly correct although in (ii) some errors due to careless transcription of the diamine structure using just 5 Cs.
		iii	(polymer) chains / molecules OR polymers have groups (unspecified or correctly specified) can <u>form hydrogen bonds with water</u> ✓	1	ANY OF secondary amide, carboxylic acids, hydroxyl and carboxyl NOT NH_2 Examiner's Comments Poor, most just rephrased the question and did not refer to what additions to the chain caused the solubility of the polymer in water

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	two from the following: is it safe? does it work? AW is it better than other substances? AW are they stable (in the human environment)? no / any side effects? ✓ ✓	1	NOT safe dose IGNORE is it toxic? Examiner's Comments Most scored both marks usually with 'safe and better'.
		v	N atom has a <u>lone pair</u> (of electrons) (May be shown on formula) ✓ can accept a proton / H^+ ✓	2	DO NOT ALLOW H / H atom / H ion ALLOW accepts protons mark separately Examiner's Comments The most common error was not to mention the N atom.
			Total	17	

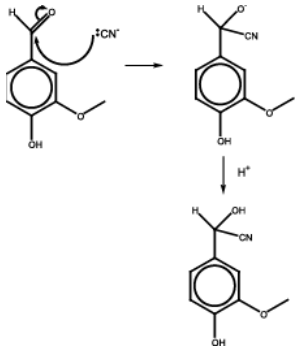
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
34	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.

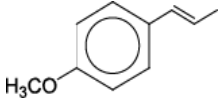
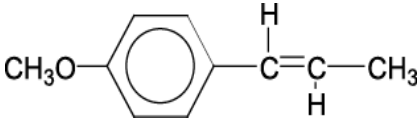
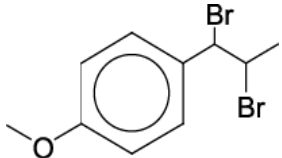
Mark Scheme

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.

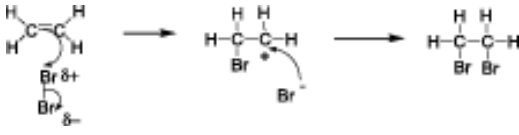
Mark Scheme

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

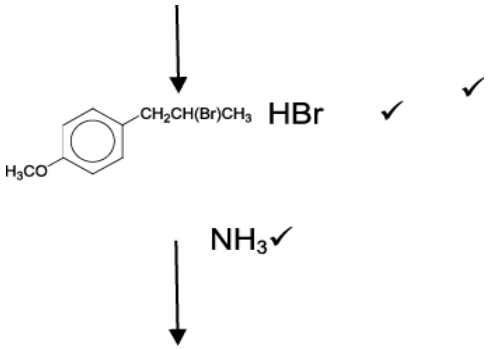
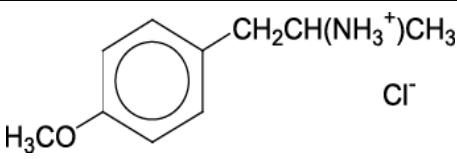
Mark Scheme

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

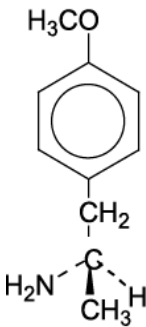
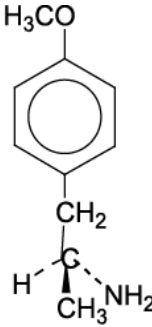
Mark Scheme

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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e	i	 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 ammonium salt.	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 ammonium salt from question e(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.

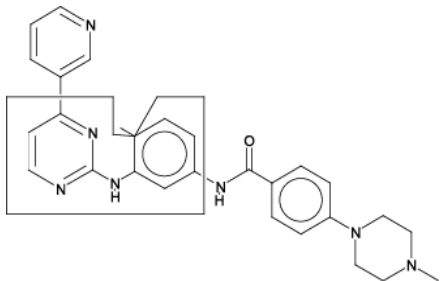
Mark Scheme

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
36	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	

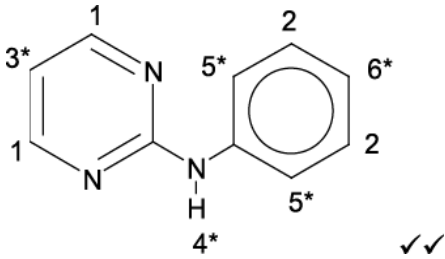
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
37	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.

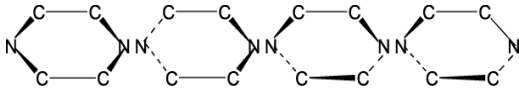
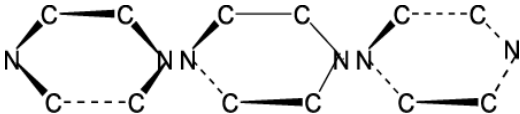
Mark Scheme

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).

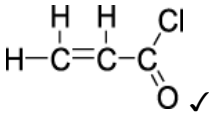
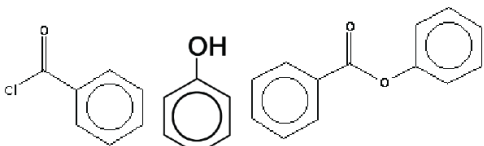
Mark Scheme

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.

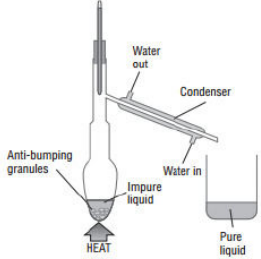
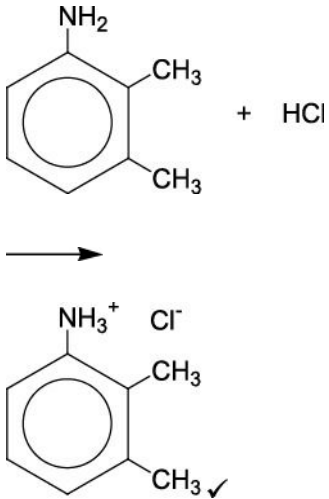
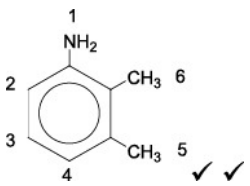
Mark Scheme

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
38		i		1	
		ii	SOCl ₂ ✓ NH ₃ ✓	2	ALLOW 'thionyl chloride' or 'sulfur dichloride oxide' ALLOW 'ammonia' Mark separately
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 14 (g) award 2 marks amount acrolein = 0.55 × 100 / (3 × 71) OR 0.258 mol ✓ mass acrolein = 0.258 × 56 = 14 (g) (2 sf) ✓	2	14.5 or 14.46... score 1 mark
			Total	5	
39				1	ALLOW any recognisable structure ALLOW Kekule structures
			Total	1	
40			C	1	
			Total	1	
41			C	1	
			Total	1	
42			B	1	
			Total	1	
43			B	1	
			Total	1	
44			C	1	
			Total	1	
45			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
46	a	i	 Correct arrangement of flask and thermometer ✓ Correct arrangement of condenser, water in at bottom, condenser not 'sealed' ✓ More volatile liquid can be collected at its boiling point ✓	3	labels not essential apart from water connection anti-bumping granules not essential
		ii		1	ALLOW 'NH ₃ Cl' ALLOW any correct equation
		iii	Add alkali/ NaOH ✓ Put in separating funnel and collect organic layer ✓	2	
	b			2	ALLOW 3,4,5,6 in any order. ALLOW 1 mark if both methyl groups have the same number OR if all both remaining arene protons are labelled '2'.

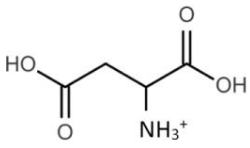
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 18.7(kg) award 3 marks Moles Mefenamic acid required =15000/241 (= 62.24) ✓ Moles 2-clorobenzoic acid needed = ans to 1st point × 100/52 (=119.69) ✓ Mass 2-clorobenzoic acid needed = ans to 2nd point × 156.5/1000 = 18.7 (kg) ✓	3	ALLOW ecf throughout ALLOW 2 or more sf
	d		<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes the appearance of the infrared and mass spectra in detail. AND Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes the appearance of the infrared. OR Describes the appearance of the mass spectra in detail. AND Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Describes the appearance of the infrared. OR Describes the appearance of the mass	6	Indicative scientific points may include: Absorbances on Infrared: • About 3300-3500 N-H amines • 2500-3300 O-H carboxylic acid • 1700-1725 C=O carboxyl ic acid • 1450-1650 several peaks Arenes • 3000-3100 C-H arenes • About 2850-2950 C-H alkyl groups Mass spectrum peaks • Molecular ion peak at 241 (allow ecf from (c)) • suggestion of a fragment (eg 196 – COOH missing) Identification of structure: • Fingerprint region unique to compound • Compare with database to confirm identity • Molecular ion gives relative molecular mass which matches that of mefenamic acid. • Fragments consistent with functional groups present

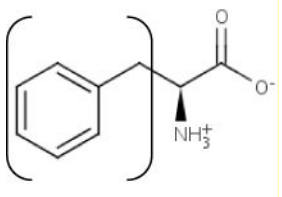
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			spectra. OR Clearly explains how mol mass, fragmentation and fingerprint region confirm identity. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit		
			Total	17	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
47	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.

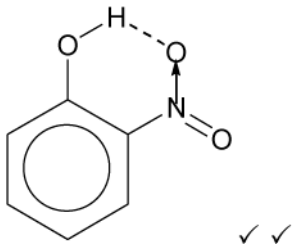
Mark Scheme

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	
48			B	1	
			Total	1	
49			D	1	
			Total	1	
50			D	1	
			Total	1	
51			C	1	
			Total	1	
52			C	1	
			Total	1	

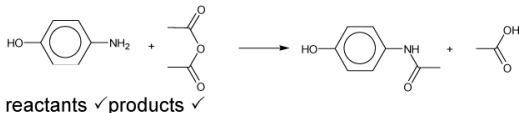
Mark Scheme

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

Mark Scheme

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

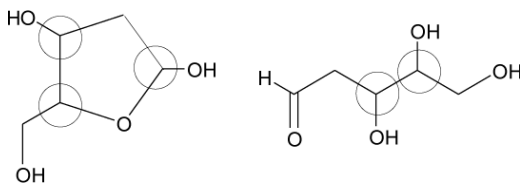
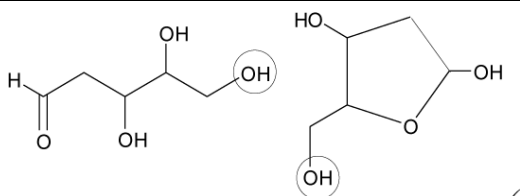
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	 reactants ✓ products ✓	2	IGNORE non-skeletal formulae / ambiguous attachments Allow correct use of Ethanoyl chloride for 1 mark Examiner's Comment: This question was generally well answered. Most candidates drew appropriate skeletal structures for the reactants, and it was pleasing to see so many correct representations for the anhydride, and subsequently identifying the products of the reaction.
		v	dissolve in minimum volume of <u>hot</u> water / solvent ✓ filter (hot solution) removing insoluble impurities ✓ allow to crystallise / AW ✓ filter, soluble impurities removed / remain in solution ✓	4	ALLOW wash (and dry) crystals - soluble impurities are washed away ✓ Examiner's Comment: There were very few blank responses to this question. Candidates often identified the steps involved in the process and could communicate this effectively. Weaker candidates often lost marks for not correctly identifying where insoluble impurities were removed, or for failing to identify the removal of soluble impurities at the end of the process. The quality of response may be linked to the use of this task within the set of expected practical's that candidates are expected to undertake as they move through the course.
	b	i	(AM404) has a similar shape to andanamide AW ✓ (AM404) fits / binds / bonds to active site ✓ (AM404 in active site) not broken down / stays on (active site)/ blocks site to / competes with andanamide AW ✓	3	Examiner's Comment: This question was generally well answered by the majority of candidates, most recognised that the shape of AM404 was similar to andanamide and that this resulted in the active site of the enzyme becoming occupied and therefore prevented the enzyme from breaking down andanamide.

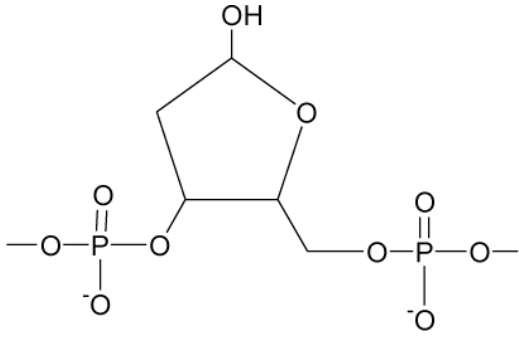
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(all) cis / Z ✓	1	Examiner's Comment: Generally well answered, the only common error was candidates who gave a response of E / Z isomerism.
		iii	lack of rotation / twisting ✓	1	Examiner's Comment: Most candidates recognised that the reason for the chain being held in its shape was due to the lack of rotation around the carbon - carbon double bond(s).
			Total	16	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
55	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	–CHO + HO– → –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.
	c	i	Base(s) ✓ Condense / react with(remaining) OH on deoxyribose ✓	2	Examiner's Comment: Again very well answered. Candidates recognised that adenine, cytosine and guanine are bases, and that they combined with the sugar phosphate backbone via a condensation reaction at the hydroxyl group of the deoxyribose ring. The most common error in this question was to suggest that the bonding between the bases and the ring was through hydrogen bonding rather than a condensation reaction.
		ii	GAC	1	Examiner's Comment: Generally well scored, the only common error was the inclusion of thymine rather than adenine in the triplet code.
		iii	leucine ✓	1	Examiner's Comment: Candidates correctly identified that leucine was the desired amino acid.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	mRNA sequence /(triplet) codon ✓ codes for / fits with tRNA (anti-codon) on amino acid ✓	2	Examiner's Comment: This question produced a variety of responses, with no common errors being evident. Most candidates recognised that there was a process whereby the sequence of bases on DNA was converted into a complimentary sequence of three bases on a strand of RNA that then proceeded to be read to produce a response that involved a strand of RNA collecting an amino acid. Where they lost marks was in not identifying mRNA or tRNA correctly, or failing to mention that it was a particular sequence of three bases (a codon or anticodon) that was necessary and linking these ideas correctly to the mRNA / tRNA, eg "DNA produces a strand of mRNA that goes to the ribosome and produces a strand of tRNA with the appropriate amino acid" or, "the sequence of three bases on the DNA produces a codon on the RNA that then produces an anticodon to select the required amino acid". These were the types of response that demonstrated that candidates understood the basic process occurring, but did not make the appropriate links required to score the marks.

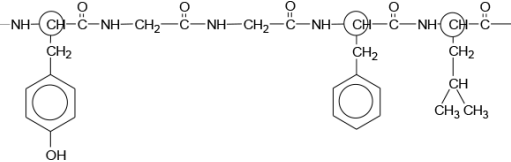
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	d	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) Structure correct and at least one piece of evidence related to the structure is provided from each spectrum. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Structure correct but does not use evidence from each spectrum OR structure not given or incorrect but at least four correct pieces of evidence given from a minimum of two spectra <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Structure correct with no evidence OR Structure not given or incorrect but at least two correct pieces of evidence given <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 include: structure $\text{CH}_3\text{OOCCH}(\text{OCH}_3)_2$ Allow $(\text{CH}_3\text{O})_2\text{CHOCOCH}_3$ infrared spectrum • C=O for ester (at 1750cm^{-1}) • C—O for ester / ether (at $1000 - 1300\text{cm}^{-1}$) • no O-H / COOH (at $2500 - 3000\text{cm}^{-1}$) ignore idea of C—H stretch / O—H stretch at approx. 3000cm^{-1} ^1H NMR • proton environments • no splitting • CH_3 groups in the same environment • all O-CH (AW) ^{13}C NMR • four C environments • C=O at $\delta = 160\text{ppm}$ • C—O at $\delta = 50\text{ppm}$ • no C—C present If incorrect bond or environment identified consider whether or not the line of reasoning has been impeded and if so, then award lower mark within a level Examiner's Comment: This question proved to be very challenging to the vast majority of candidates. It was targeted to be of high demand. Most candidates made a very good attempt at the question and often produced a detailed response where they identified many of the key features of the structural isomer using all three spectra as instructed in the question. Most candidates correctly identified the presence of a C=O group from both the IR spectrum and the CNMR spectrum, they also correctly

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					identified that there were 3 proton environments from the proton NMR spectrum, and that there were 4 carbon environments from the CNMR spectrum. However, many candidates insisted that the molecule contained OH groups from incorrectly identifying this group from the IR spectrum. The peak at approximately 3000cm^{-1} indicated the presence of C—H bonds as it was not a broad peak associated with OH groups in a variety of molecular environments that would have been characterised by a broad peak. Consequently they then identified the O—CH peaks in the HNMR spectrum as being associated with an alcohol rather than an ether, even though many had identified a C—O stretch from the IR spectrum at $1000 - 1300\text{cm}^{-1}$. As a result of this many candidates proposed structures containing OH groups which were incorrect, but were rewarded for their interpretation of the various spectra at L2 with many scoring 4 marks.
			Total	22	
56			B	1	<u>Examiner's Comments</u> D was the most frequently seen incorrect answer.
			Total	1	
57			A	1	<u>Examiner's Comments</u> This is a new topic to the current specification and candidates found it relatively difficult.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
58	a		The 3D shape OR the shape produced by the folding of the protein molecule ✓	1	<u>Examiner's Comments</u> This was well done by the vast majority of candidates.
	b		Any two from: ✓ Instantaneous dipole-induced dipole hydrogen bonds ionic bonds covalent bonds	1	IGNORE specific groups mentioned after bond types. <u>Examiner's Comments</u> There were some answers that used 'lock and key theory', rather than naming the actual bonds between enzyme and substrate.
	c	i	 All required ✓	1	ALLOW C or CH ringed Extra carbons ringed are CON <u>Examiner's Comments</u> This was well done. Occasionally extra carbons were circled or incorrect ones such as the C=O groups.

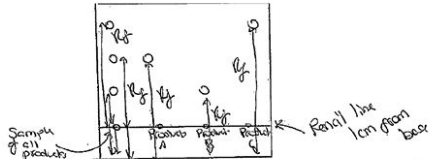
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
ii	$+H_3N-CH-C(=O)OH$ $$ CH_2  OH $+H_3N-CH_2-C(=O)OH$ $$ $+H_3N-CH-C(=O)OH$ $$ CH_2  $+H_3N-CH-C(=O)OH$ $$ CH_2 $$ CH $/ \quad \backslash$ $CH_3 \quad CH_3$ ✓ ✓ ✓ one for each	4	ALLOW ECF if all the NH^{3+} groups are not protonated IGNORE Cl^- ions. IGNORE number of moles of aminoethanoic acid. Structures with deprotonated carboxylate groups score 0 (no ECF) Extra incorrect structures CON a correct one <u>Examiner's Comments</u> The things required here were: knowing how a protein is hydrolysed, getting the correct structures of the products, and modifying them appropriately to account for the acidic conditions. There were a number of perfect answers with all the NH_2 groups protonated and quite a few who lost one mark because they were not. Others lost all the marks because they had acid chlorides, aldehydes or other incorrect functional groups in the products.
d	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Gives a clear and detailed account of all three parts, including most of the points listed. <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) Gives an outline account of all three parts OR gives a detailed account of two parts. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i>	6	Indicative scientific points may include: Developing • spray with ninhydrin ALLOW UV light • dry (in an oven/ fume cupboard) Chromatogram • Start line • Starting dot of hydrolysate OR Dots of suspected hydrolysis products for reference • (four spots above) • Spots level with suspected hydrolysis products • Mark position of solvent front • Lid

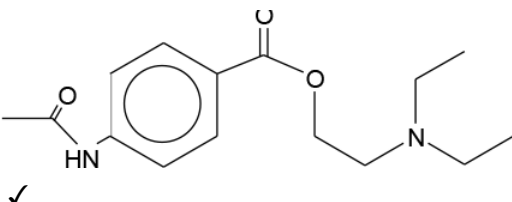
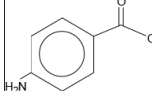
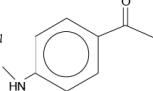
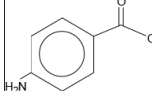
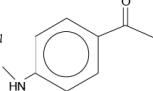
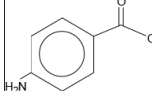
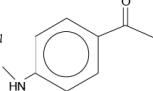
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Level 1 (1–2 marks) Makes some relevant points <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		• Stop when solvent gets near the top of the paper Analysis • Measure R_f values of spots • R_f = distance moved by spot/distance moved by solvent front • Look up R_f values for the three amino acids • Compare with measured values OR Compare R_f values with reference amino acids IGNORE use of tlc plate instead of paper <u>Examiner's Comments</u> This was an experiment that candidates knew well and could describe logically. Many realised the advantages of annotated diagrams, both for setting up the experiment and calculating R_f values. In some cases, the incorrect or no locating agent was given. 'Iodine crystals' was a frequent incorrect answer. Some did not fully explain what R_f was and how it could be calculated, and others called it 'retention factor'.

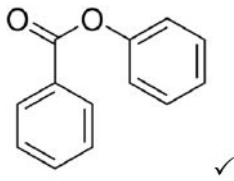
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 9  A sample from the reaction containing all 3 products should be dotted onto the baseline, (drawn in pencil, 1cm from bottom of paper). Then a sample of each of the 3 products should be dotted onto the paper on the baseline. A suitable solvent should be chosen and placed in a beaker so it won't submerge the paper above the pencil line. The paper can then be placed in the beaker, and a lid must be placed on the beaker to ensure the solvent does not evaporate. Once the solvent front reaches the top of the paper, the paper can be removed and sprayed with iodine vapor to reveal the dots. R_f values can then be measured by dividing the distance of the dot from the bottom of the paper by the height of the paper. Compare its value to identify the different products of hydrolysis. In this answer the candidate has given a good account of how to get the chromatogram, but the position of the solvent front is not marked. The developing section uses the incorrect locating agent, iodine, rather than ninhydrin and does not mention drying the chromatogram. The analysis section makes some points but is vague about how to calculate R_f values and what to compare them to. Overall we thought this was a Level 2 answer but the explanations did not include sufficient detail to give more than 3 marks. This candidate has included a diagram in the answer and it is possible to credit points made on a labelled diagram. Unfortunately in this case the detail on calculating R_f was absent here too.
	Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance									
59	a	i	NaOH(aq) AND (Heat under) Reflux ✓	1	ALLOW warm for reflux <u>Examiner's Comments</u> Fewer than half the candidates scored here as they chose acid hydrolysis despite the sodium salt of C being formed. There were also quite a few instances of water as the reagent.									
		ii	Acidify (until neutral) ✓ Filter off C OR evaporate to give C ✓	2	ALLOW any dilute named acid. <u>Examiner's Comments</u> Filtration was frequently seen, but acidification was much rarer. Distillation was a popular answer.									
		iii	 ✓	1	ALLOW any unambiguous representation ALLOW C ₁₅ H ₂₂ O ₃ N ₂ if both shown an incorrect formula CONs a correct structure or vice versa <u>Examiner's Comments</u> A significant number of candidates omitted this question as they found it difficult to apply their knowledge of simpler amines reacting with acid chlorides to this example.									
	b		<table border="1"><thead><tr><th>Monomer</th><th>Repeat unit</th><th>Type of polymerisation</th></tr></thead><tbody><tr><td>CH_2 $\text{CHN}(\text{C}_2\text{H}_5)_2$</td><td>$\text{---} \begin{array}{c} \text{H} \quad \text{N}(\text{C}_2\text{H}_5)_2 \\ \quad \\ \text{---C---C---} \\ \quad \\ \text{H} \quad \text{H} \end{array} \text{---}$</td><td>Addition</td></tr><tr><td></td><td></td><td>Condensation</td></tr></tbody></table> Completely correct – 2 marks; 1 mark for a correct row or column	Monomer	Repeat unit	Type of polymerisation	CH_2 $\text{CHN}(\text{C}_2\text{H}_5)_2$	$\text{---} \begin{array}{c} \text{H} \quad \text{N}(\text{C}_2\text{H}_5)_2 \\ \quad \\ \text{---C---C---} \\ \quad \\ \text{H} \quad \text{H} \end{array} \text{---}$	Addition			Condensation	2	ALLOW any unambiguous representation. <u>Examiner's Comments</u> The type of polymerisation was often correct, but candidates often struggled to give correct repeat units. Joining polymer D from the nitrogen or even retaining the double bond were both seen. For polymer E 2 repeat units were sometimes given.
Monomer	Repeat unit	Type of polymerisation												
CH_2 $\text{CHN}(\text{C}_2\text{H}_5)_2$	$\text{---} \begin{array}{c} \text{H} \quad \text{N}(\text{C}_2\text{H}_5)_2 \\ \quad \\ \text{---C---C---} \\ \quad \\ \text{H} \quad \text{H} \end{array} \text{---}$	Addition												
		Condensation												
			Total	6										

Mark Scheme

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

Mark Scheme

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

Mark Scheme

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

Mark Scheme

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

Mark Scheme

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

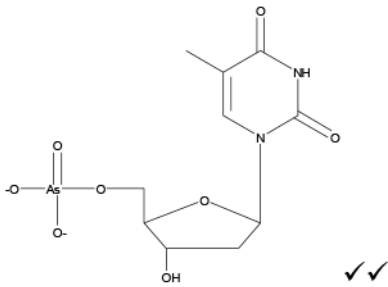
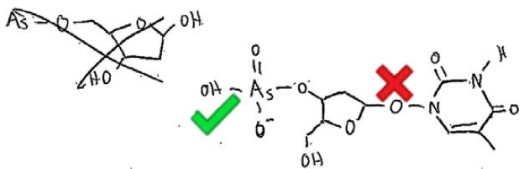
Mark Scheme

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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
62	a		will not allow formation of S-S bonds	1	ALLOW idea that As interferes with sulfur bridges / S-S bonds in the protein Examiner's Comments Question 5 required that centres had given candidates time and opportunity to study the pre-release article "The Strange Story of Napoleon's Wallpaper". It was anticipated that teachers would have spent some time discussing some of the chemistry within the article. The focus of the article should have prompted teachers to guide candidates towards looking at the properties and reactivity of Group V elements, nitrogen and phosphorous. These could be used to predict some of the reactions and properties of arsenic by extending the group trend(s). In part (a) most candidates recognised that the removal of the –SH groups would interfere with the ability of the protein to form the correct tertiary structure. However, to score the mark here they had to make it clear that the arsenic was preventing the formation of S—S bonds (disulfide bridges). It was pleasing to see that in the vast majority of responses that this was the answer given.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b		2	ALLOW arsenate group partially, or fully protonated bonded to either OH group on the ribose ring for 2 marks Correct structure with one error scores 1 mark <u>Examiner's Comments</u> In part (b) candidates needed to make use of the relevant section from the Data Sheet provided. They needed to select the appropriate sugar structure (deoxyribose) and derive the structure of thymine. Finally they needed to substitute As for P in the phosphate group and then join the fragments together in order to produce the correct structure. Many candidates succeeded in this and scored both of the marks available. The two most commonly seen errors were the inclusion of a bridging O atom between the thymine molecule and the deoxyribose ring, or the omission of the C=C within the thymine structure. Exemplar 11  Exemplar response showing the incorrect depiction of a bridging O between thymine and the deoxyribose ring

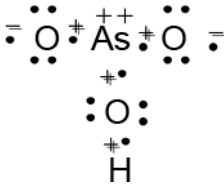
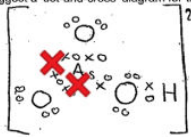
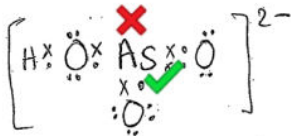
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		$2\text{As}^{3+}(\text{aq}) + 3\text{H}_2\text{S}(\text{g})/(\text{aq}) \rightarrow \text{As}_2\text{S}_3(\text{s}) + 6\text{H}^+(\text{aq})$ balanced equation ✓ Correct state symbol for As_2S_3 ✓	2	<u>Examiner's Comments</u> This was found difficult by candidates, with. Most candidates did not realise the need to balance the charges within the equation and so gave $3\text{H}_2(\text{g})$ as a product rather than $6\text{H}^+(\text{aq})$, losing 1 mark. Many gave the formula of $\text{As}_2\text{S}_3(\text{s})$ in an unbalanced equation, and this was allowed for 1 mark.
	d	i	generating flask containing zinc, sulfuric acid and As_2O_3 ✓ heated tube leaving flask ✓ silvery-black film / Arsenic (metal) labelled ✓	3	ALLOW 'sample' for As_2O_3 IGNORE closed tube <u>Examiner's Comments</u> This was a well answered question and most candidates scored full marks. There were some examples of apparatus that, whilst being impractical or potentially dangerous, did match to the description given in the pre-release material. The marks were not for designing something that would meet today's Health and Safety requirements, but for recognising candidates' ability to extrapolate a description into a suitable diagram of a set up that might work. Therefore sealed tubes, or open tubes with hydrogen escaping near a naked flame, did not result in the loss of any marks. The only common error evident was in failing to label the apparatus appropriately (e.g. failing to label where the arsenic metal would be deposited, or failing to label the heating of the glass tube leaving the reaction flask) Marks were lost through carelessness rather than an inability to produce a suitable diagram..

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\text{As}_2\text{O}_3 + 6\text{H}_2 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} \checkmark$ $2\text{AsH}_3 \rightarrow 2\text{As} + 3\text{H}_2 \checkmark$	2	ALLOW $\text{As}_2\text{O}_3 + 6\text{Zn} + 6\text{H}_2\text{SO}_4 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} + 6\text{ZnSO}_4$ for equation 1 IGNORE state symbols <u>Examiner's Comments</u> Many candidates did not write a balanced equation for the formation of arsine in the reaction vessel, but were able to write a balanced equation for the decomposition of arsine to form arsenic and hydrogen as the products and so scored 1 mark here. In the first equation a common error that was observed was the inclusion of oxygen gas, O_2, as one of the products of an otherwise balanced equation, which resulted in the mark not being credited.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
e i	 8 electrons around As atom ✓ completely correct including lone pair on As ✓	2	ALLOW 'spare' electrons on oxygen as different symbol or the same as others on that oxygen IGNORE overall charge of 2- Examiner's Comments A number of candidates identified the anion present in <i>Scheele's Green</i>, but were unable to then draw the appropriate dot and cross diagram. The most common errors were to produce diagrams containing double bonds to one or more oxygen atom giving ten or more electrons around the central As atom, failing to include a lone pair of electrons on the As atom, and failing to check that each oxygen atom satisfied the octet rule. Exemplar 12 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  Commonly seen incorrect dot and cross diagram for bonding of Scheele's Green anion. Exemplar 13 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  No lone pair on central As atom, but each atom has its full complement of electrons around its outer shell arrived at by drawing a double bond to one of the oxygen atoms.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Cu^{2+} (ion) ✓	1	ALLOW Copper(II) / copper ion <u>Examiner's Comments</u> Most candidates scored this mark as they recognised that coloured substances usually contain a transition metal ion, and so gave Cu^{2+} or copper(II) as their answer. The only common errors were the omission of the charge on the ion, or the omission of the oxidation state after the name of the element.
	f		107.5 (°) ✓ Four pairs of electrons (around As) ✓ Repel and get as far away as possible / move apart to minimise repulsion ✓ Lone pair : bond pair repulsion > bond pair : bond pair repulsion / lone pair repels more (than bond pair) / lone pair takes up more room (AW) ✓	4	ALLOW 107 – 108 ALLOW 'areas of electron density'/'groups of electrons' for 'pairs of electrons' / 3 bonding pairs AND 1 lone pair must be clear that it is electrons repelling to score third mark <u>Examiner's Comments</u> Most candidates scored at least three marks here, and many went on to score all four marks. The only common omission was in failing to make it clear that the lone pair of electrons present on the central arsenic atom had a stronger repulsion on the bonding pairs of electrons and that this produced the bond angle of 107.5°.

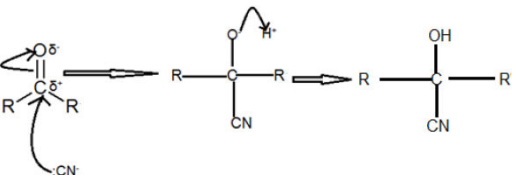
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	g		Any three from: arsenic found in Napoleon's hair ✓ wallpaper (might have) contained arsenic /contained Scheele's Green ✓ Dampness / mould on the wallpaper released toxic arsenic vapours ✓ wallpaper poisoned others ✓	3	ALLOW (wallpaper) linked to Gosio's Disease <u>Examiner's Comments</u> Most of the candidates were able to provide a response here that scored two if not all three marks. They had clearly studied the pre-release material appropriately and were able to summarise the three key pieces of evidence accurately. Where candidates only scored two marks was often a result of omitting marking point 1 – that traces of arsenic were found in the sample of Napoleon's hair. Most candidates made the link between the Scheele's Green pigment found in the wall paper sample, and that the island environment would have caused the paper to become mouldy. This would then result in releasing toxic arsenic compounds as a vapour that Napoleon would have been exposed to over a period of time.
			Total	20	

Mark Scheme

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

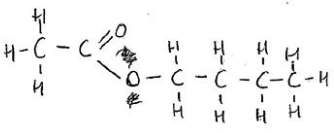
Mark Scheme

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

Mark Scheme

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

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 8 The IR shows no O-H peak due to the lack of a broad peak at 3000 but a less broad peak shows C-H from alkanes are present. The peak 1700 shows a C=O is present and at 1750 shows an ester C=O is present. The ¹H NMR peak at 4.0 ppm shows there is 2 H on the carbon to the H-C=O of the ester. The multiplet H-C-R suggests a methyl CH₃ at the end of chain and the along side with the different shift shows the different hydrogen environments. The Quartet peak at 2.0 ppm shows 3 hydrogens on the carbon adjacent to the CH=O making it a methyl alkyl ester group. The Mass spec gives the Mr of 116 which when 6 carbons are known each have 12 Hydrogen and 2 oxygens present. Structure of compound A  [5] This candidate has correctly identified all the absorbances on the infra-red spectrum and did not confuse the C-H absorbance with O-H as some did. They have used the molecular ion peak on the mass spectrum with other data to get the molecular formula, although they have not considered the fragments. They have correctly identified the chemical shifts of protons next to the ester group and made an attempt at interpreting the splitting. They have deduced the structure is that of an ester, but they have not quite used the splitting pattern and the fact that it could be made from propene to get the correct ester. This response was therefore judged to be at Level 2, and credited 4 marks.
	Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
64	a		Any three from: Active site has complementary shape to hydrogen peroxide (molecule) ✓ H₂O₂ binds/fits to active site ✓ bonds broken more easily ✓ Ea lowered ✓ .	3	ALLOW 'substrate' for H₂O₂ throughout ALLOW forms enzyme-substrate complex <u>Examiner's Comments</u> This question was well attempted by most candidates, with many scoring at least two marks. Most candidates recognised that the hydrogen peroxide fits into the active site on the catalase (forming an enzyme – substrate complex), and that this resulted in a lowering of the activation enthalpy which increased the rate of reaction. Very few candidates made any reference to the fact that the complex formed resulted in the bonds within the peroxide molecule being broken more easily. Higher ability candidates often started their response by indicating that the active site in catalase has a complementary shape to the hydrogen peroxide and therefore scored all 3 marks.

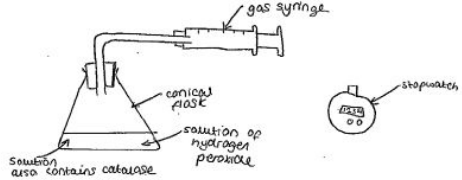
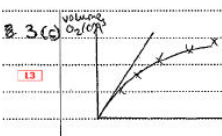
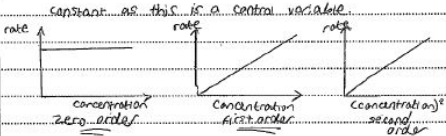
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	<i>Please refer to the marking instructions on page 6 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5 – 6 marks) Detailed procedure with most key variables identified and includes some relevant fine detail (may or may not include a diagram). AND Explains clearly how to process results. <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) Workable procedure with some variables identified may include some relevant fine detail (may or may not include a diagram). AND Attempts to explain how to process results. <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) Outline of procedure with some variables given (may or may not include a diagram). OR Attempts to explain how to process results. <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: AO3.3 Development of a practical procedure by analysing information <i>Key variables may include:</i> • flask with peroxide; • same volume of peroxide solutions • keep concentration (and volume) of catalase • constant • vary peroxide concentration; • volume of oxygen measured in gas syringe or • over water; <i>Fine detail may include:</i> • means of adding catalase / starting reaction; • time for certain volume of oxygen to be produced • record volume of oxygen produced at fixed time • intervals • suitable apparatus for measuring volumes of solutions • suggests appropriate volume of gas to be collected • suggests appropriate time intervals for measuring volume of gas AO3.1 Processing results <i>Makes reference to</i> (plots) graph of volume of oxygen produced • against time; • measures slope at the origin / time $t = 0$; • rate proportional to $1/\text{time}$ for a small volume of • oxygen to be produced • uses $\text{rate} = \text{vol of oxygen}/\text{time}$ • use of smallest rate value to calculate relative • rates NB: Some of the above indicative science may be addressed as part of a labelled

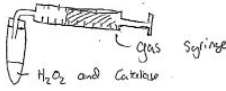
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					diagram – accept any relevant diagram even if poorly drawn. Allow sketch graph labelled as evidence of method used to process experimental data collected. <u>Examiner's Comments</u> This Level of Response question was well tackled by the vast majority of candidates. Most candidates scored at Level 2, with higher ability candidates regularly scoring at Level 3. There were two strands to this question that candidates needed to address; (i) designing a suitable procedure giving essential details (including some relevant fine detail), and (ii) explaining how they would process the data that they had collected. This is a practical procedure that candidates should be familiar with. Candidates should be able to describe a suitable workable method for this reaction, and indeed this was often the case. Many candidates produced diagrams of the apparatus which were a good indicator that their response was likely to be at least at Level 2 in the first strand. The second strand of this question provided an element of discrimination. Candidates were required to explain how they would process their results; some produced outlines of the graphs that they would plot indicating the tangent to be drawn, which again gave examiners a quick idea of what the appropriate level was likely to be. However, whilst many knew that they needed to produce a graph, they often suggested using a concentration vs rate graph, which was incorrect within the context of this question. This often meant that candidates who had produced a very detailed method were limited to Level 2 as the processing strand was weak. Where candidates did not address one of the strands within their response,

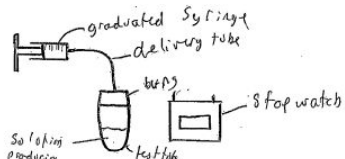
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			unfortunately this resulted in them being limited to Level 1. Exemplar 6  Known • Measure out equal volumes of different concentrations of hydrogen peroxide solution (eg. 25.0 cm³) using a burette or volumetric pipette. A clean, dry pipette can be used to run the solution into a clean conical flask. • Add a fixed volume of enzyme ~~catalase~~ catalase solution to the conical flask, stopper the flask and start the stop watch. The conical flask should be connected to a gas syringe to collect the oxygen gas formed. • At equal time intervals (eg. every 10 seconds) measure the volume of oxygen in the gas syringe to the nearest 0.05 cm³. • Keep doing this for 2 minutes, or until no more gas is produced. Repeat this procedure for all different concentrations of hydrogen peroxide. • Record results in a table of volume of oxygen (cm³) against time (s) and use this to plot a graph of volume of oxygen against time. * Please see back page for the rest *  Draw a line of best fit. Draw a tangent to the curve at time $t=0$ and use the gradient to work out the initial rate of reaction. Then plot a graph of initial rate (y-axis) against concentration of hydrogen peroxide. This will tell you the rate of reaction with H_2O_2. The amount of catalase needs to be kept constant as this is a control variable.  rate concentration zero order concentration first order concentration second order Level 3 response, scoring 6 marks. This includes all key variables, and a significant amount of fine detail, explaining clearly how to process the results collected. The answer continues onto additional space of answer booklet. Whilst this was a Level 3 response, the candidate could have made their answer more succinct. Candidates are advised that

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			the answer space provided should be sufficient to gain full marks for Level of Response questions, without needing to continue onto the additional answer space. In this case, the candidate could have omitted the superfluous discussion and diagrams of rate-concentration graphs they have included at the end of their response. The suggested procedure could also have been written more concisely whilst retaining sufficient detail to receive full credit. Exemplar 7  The student will firstly produce equal moles of Catalase and H_2O_2 and the same concentration of Catalase. They will be used. Produce at least 5 different H_2O_2 concentrations. The student will measure the volume of gas being produced for each different concentration of H_2O_2 for a set interval of time (2 mins) using a stopwatch. This means for each concentration of H_2O_2 you will know the volume of O_2 produced by the recordings of the gas syringe after the set time of 20 minutes. Repeat the procedure 10 times for each H_2O_2 concentration. The student can plot a graph of ~~concentration~~ volume of H_2O_2 produced vs time (x-axis). Next plot the volume of H_2O_2 concentration. Draw a line of best fit for each of the graphs produced for each H_2O_2 concentration. Next produce a tangent at $t=0$ for each H_2O_2 concentration graph and calculate gradient of tangents ($\frac{\Delta y}{\Delta x}$) and therefore you will know the initial rate of reactions for each H_2O_2 concentration. Level 2 response, scoring 4 marks. A workable procedure is outlined, but lacks fine detail which would have allowed the candidate to progress to Level 3. Good explanation of processing of results.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance															
					Exemplar 8  Soaking producing oxygen (hydrogen peroxide) Method 1) Place a known volume of hydrogen peroxide in the test tube. Add the catalyst. Start the timer and place the bung in the top of the test tube. 2) Record how long 50 cm³ of oxygen takes to be produced. Record the final time. 3) Repeat 3 times with the same volume. 4) Increase volume of hydrogen peroxide by 10 cm³ and repeat for 6 results. Process Results - 50 of oxygen = 1 cm³ - find moles of O₂ produced with $n = \frac{pV}{RT}$ - 1:2 ratio. ~~double~~ the n_{O_2} for moles of H₂O₂ - $n = CV$ - concentration of hydrogen peroxide = $\frac{\text{moles}}{\text{Volume}}$ Level 1 response scoring 2 marks. Provides an outline of a method that might work but makes no reference to the use of time to calculate a rate value.															
c	i	<table><tr><th>[H₂O₂]/ mol dm⁻³</th><th>(relative) rate</th></tr><tr><td>0.05</td><td>1.0</td></tr><tr><td>0.10</td><td>2.1</td></tr><tr><td>0.15</td><td>3.0</td></tr><tr><td>0.20</td><td>3.8</td></tr><tr><td>0.25</td><td>4.0</td></tr><tr><td>0.30</td><td>4.1</td></tr><tr><td>0.35</td><td>4.1</td></tr></table>	[H ₂ O ₂]/ mol dm ⁻³	(relative) rate	0.05	1.0	0.10	2.1	0.15	3.0	0.20	3.8	0.25	4.0	0.30	4.1	0.35	4.1	2	First mark for labelled columns (or rows). ALLOW 'concentration of H₂O₂' for [H₂O₂], Evidence of units required for Hydrogen peroxide. Accept 'au/arb' for relative rate but no other units allowed. Other units = CON Second mark for correct values, all concentration values to 2 dp, rate values to 1dp. IGNORE inclusion of temperature
[H ₂ O ₂]/ mol dm ⁻³	(relative) rate																			
0.05	1.0																			
0.10	2.1																			
0.15	3.0																			
0.20	3.8																			
0.25	4.0																			
0.30	4.1																			
0.35	4.1																			

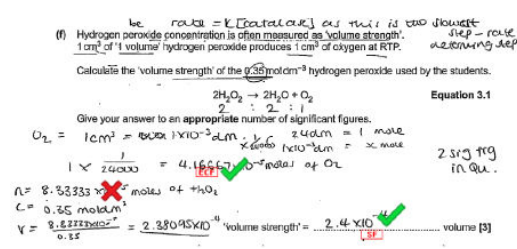
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	labelled axes (ignore units) with rate as y-axis✓ plot points correctly✓ draws best fit line ✓ (must go through the origin) each scale chosen to take up more than half axis ✓	4	ALLOW +/- ½ small square Line should pass through at least 5 points / pass within 1 small square of their plotted points <u>Examiner's Comments</u> This question was generally well answered, with most candidates scoring at least 4 marks, and many scoring the full 6 marks. The only common errors were in part (i) the inclusion of some units for the rate of reaction column, and in (ii) reversing the x and y axis. Some candidates did lose one mark in part (ii) for failing to choose an appropriate scale to use that should have taken up a minimum of half the space available.
	d	i	Rate = $k[\text{H}_2\text{O}_2]$ ✓ [catalase] ✓ $\text{dm}_3 \text{ mol}^{-1} \text{ s}^{-1}$ ✓	2	ALLOW [enzyme] for [catalase], (must have 'rate =' at start of their expression) ALLOW units in any order <u>Examiner's Comments</u> This was a tricky question for many candidates. Most struggled to work out the units for the rate constant. The only other common error was the omission of "rate =" at the start of the rate equation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	peroxide: first order initially ✓ then zero order ✓ catalase: no evidence since concentration not changed (AW)✓	3	ALLOW concentration of catalase kept constant <u>Examiner's Comments</u> There were a lot of varied responses to this question. The majority of candidates scored at least one mark, but very few scored all three. Many candidates used the graph in d(ii) to state that 'up to 0.2mol dm^{-3} (or, at low concentration) the reaction is first order with respect to hydrogen peroxide as the graph is a straight line'. Some also scored a second mark for realising that when the graph levelled off the rate became zero order as no matter how the concentration of peroxide changed, there was no further change in rate. They then tended to link this to the idea of the active sites being saturated. Very few candidates identified that the statement was incorrect with regard to catalase as the catalase concentration was kept constant in this reaction.
	e		FIRST CHECK ANSWER ON ANSWER LINE If answer = 4.2 award 3 marks $(0.35/2 =) 0.175$ mol oxygen per dm^3 peroxide ✓ volume strength $(= 24 \times 0.175) = 4.2$ ✓ answer to 2sf ✓	3	If answer = 8.4 award 2 marks for candidate failing to convert 0.35 to 0.175 ALLOW ecf from incorrect calculation of number of moles Any calculated value to 2sf scores 1 mark. <u>Examiner's Comments</u> This question was a good discriminator , producing a full range of marks from 3 to 0. Lower ability candidates often struggled to score any marks here. Higher ability candidates also found this challenging. The most common mark was credited for

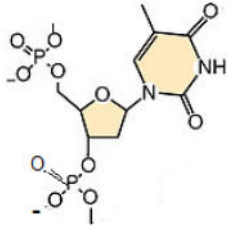
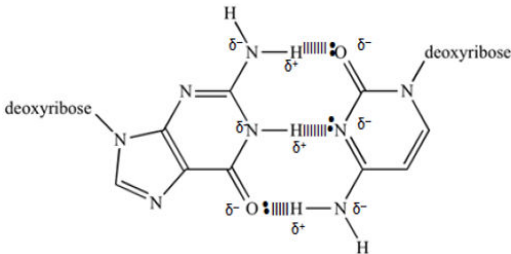
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					identifying that the molar ratio between the peroxide and oxygen was 2:1, and so the moles of O₂ should be 0.175 (or 1.75×10^{-4} if converted from dm³ to cm³). Where candidates subsequently lost marks was in the next step for not realising that because oxygen is a gas, they needed to multiply their calculated number of moles by 24(dm³) or 24000(cm³) to then arrive at the final answer. This question included a mark that was for displaying their working, in order that where a candidate had not spotted the molar ratio, or had calculated the number of moles of oxygen by a different method, then examiners could award a mark for the use of '× 24 (or 24,000)' as an error carried forward with the final mark being for converting their calculated value to 2 significant figures. A candidate who simply gave an incorrect final answer to this question scored 0, whereas candidates who did not arrive at the correct final answer but had displayed their working often scored 2 marks. Exemplar 9  Calculation showing working being given credit, even though final answer is incorrect.
	f		FIRST CHECK ANSWER ON ANSWER LINE If answer = 120 (cm³) award 2 marks (total volume =) $20 \times 0.35/0.05$ OR 140 (cm³) ✓ volume to add = 120 (cm³) ✓	2	ALLOW 140(cm³) even on the answer line for 1 mark Examiner's Comments Generally well answered. Most candidates scored at least one mark for arriving at an answer of 140 cm³, as they did not subtract the initial 20 cm³ of peroxide solution.
			Total	25	

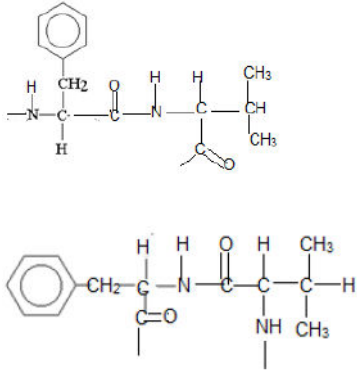
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
65			D	1 AO 1.1	<u>Examiner's Comments</u> This proved quite a difficult question; B was the answer given by many candidates, as was C, perhaps as equations involving carboxylates of divalent metals look unfamiliar.
			Total	1	
66			B	1 AO 1.1	<u>Examiner's Comments</u> Many candidates annotated option 3 with the word complementary and chose the correct answer, B. Others selected option A, all three correct.
			Total	1	
67			C	1 AO 1.1	<u>Examiner's Comments</u> Many candidate answers to this question assumed that all amino acids had a chiral centre. While this is true for almost all amino acids, it is not true of glycine.
			Total	1	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
68	a	 BOTH bonds between phosphate and sugar ✓ Bond between sugar and base ✓ All other details correct ✓	3 AO 1.2 x 3	ALLOW phosphates with minus sign or 'spare bonds' or -OH groups <u>Examiner's Comments</u> This was well done; many candidates scored full marks. If fewer marks were scored it was because a CH₂ group was missing on the deoxyribose unit, or there was an oxygen atom between the sugar and thymine, or the structure of thymine was incorrectly drawn.
	b	 3-H bonds ✓ 3 partial charges across at least 1 H-bond ✓ Lone pair along the bond axis in at least 1 H-bond ✓	3 AO 1.2 x 3	any other number of H-bonds is CON <u>Examiner's Comments</u> Candidates most frequently scored 2 marks for this question. We have not asked this for a number of years and marks were lost because the partial charges were not included on all three atoms across the hydrogen bond, or lone pairs were not placed along the direction of the bond.

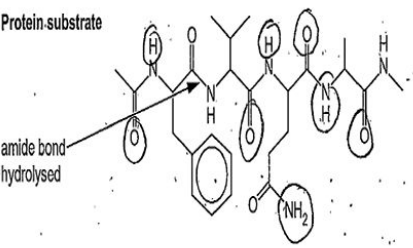
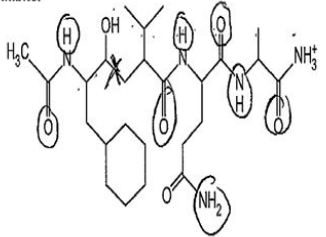
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
c	 Amide link between phenylamine and valine ✓ Rest of structure ✓	2 AO 2.5	ALLOW either structure MUST have spare bonds at the ends of the section to score second mp IGNORE brackets around entire unit <u>Examiner's Comments</u> This was difficult question. Some candidates had an oxygen atom in the middle of the amide link, but many lost a mark because they did not draw 'a section of a protein molecule' and hence leave the 'end bonds' open, rather than NH₂ or COOH.
d	Level 3 (5–6 marks) Detailed explanation of how the enzyme and inhibitor work in general AND relates these ideas to the structures of the molecules given. <i>There is a well-developed line of reasoning which is clear and logically structured.</i> Level 2 (3–4 marks) Detailed explanation of how the enzyme and inhibitor work in general. OR An attempt at an explanation of how the enzyme and inhibitor work in general AND relates these ideas to the structures of the molecules given. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Detailed explanation of how the enzyme works in general. OR Detailed explanation of how the inhibitor work in general. OR An attempt at an explanation of how the enzyme and inhibitor work in general.	6 AO 2.2 x 4 3.1 x 2	Indicative scientific points may include: How the enzyme works, general comments: • Substrate fits/binds into the active site • Substrate has complementary shape to active site (ORA) • Bonds weaken/Lowers EA/biological catalyst • Substrate reacts • Products leave the active site How the inhibitor works, general comments: • Inhibitor has a similar shape to the substrate (AW) • so it also fits into the active site • It blocks the active site/doesn't release • substrate cannot bind (and react) • Fewer/ no active sites available to the substrate so slower/ no reaction Comments specific to these molecules: • Example of where these molecules share some of the same shapes (check for annotation on the diagram) • Middle part of the molecule has similar shape • Example of intermolecular interaction between these molecules and enzyme

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			OR An attempt to relate how enzymes work to ideas to the structures of the molecules given. <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.		• Substrate has amide bond that can be hydrolysed, and products leave • Inhibitor has no amide bond (in the same place) so does not react and leave • Comments on other differences that may affect the binding of the inhibitor vs substrate. <u>Examiner's Comments</u> Many answers focused on detailing primary, secondary and tertiary structure details as well as the types of bonds used to bind to active site, rather than addressing the exact demands of the question. The answers tended to focus on enzymes and inhibitors in general, rather than using the specific structures given in the question to suggest areas of commonality between molecules and why one would be able to act as an inhibitor. This could have been accomplished with annotations on Fig. 32.2 and 3. Most answers were Level 2 as a result.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 6 Protein substrate  amide bond hydrolysed Fig. 32.2 The substrate in Fig. 32.3 acts as an inhibitor to the HIV protease enzyme. HIV protease inhibitor  Fig. 32.3 Explain how an enzyme works and suggest how the HIV protease inhibitor affects the function of the protease enzyme. [6] An enzyme has a region called the active site. It has a very specific region shape caused by its tertiary structure that exactly complements the shape of the substrate. Groups within the substrate form bonds to the enzyme, which cause bonds within the substrate to break and products to form. The HIV protease inhibitor has almost the same shape as the desired protein substrate. I have circled the groups which both substrates contain which can bond to the enzyme. This means the HIV protease inhibitor fits the shape of the enzyme.

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					and bonds to it. However, there is no peptide link in HIV protease inhibitor. The peptide link in the protein substrate that is broken by the enzyme is Additional answer space if required not in the HIV protease inhibitor. This means the inhibitor will not break up and will not be released from the enzyme. This prevents the enzyme from going on and catalysing the breakdown of the protein substrate. This response has addressed all the ideas clearly, and has annotated the diagrams of the structures provided to clearly identify elements of commonality.
			Total	14	

Mark Scheme

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69	a		(A molecule that has) non-superimposable mirror images ✓ correct 3D structural formula shown $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ ✓ correct use of wedges (dots) and dashes to show mirror images ✓	3(AO 1.1)(AO 2.1x2)	Ignore references to C has four different groups.  would score MS2 and 3 One mark scored for one of above structures Don't worry about reflections of –OH, –COOH and etc. DO NOT ALLOW two 'lines' at 180 <u>Examiner's Comments</u> Many responses to this question were expressed in terms of the structure needed in a molecule for it to be chiral, rather than the properties of a chiral molecule such as lactic acid. Examiners were looking for the idea of non-superimposable mirror images (enantiomers) as well as correctly drawn 3D mirror image structures for the lactic acid molecule.
	b	i	ester ✓ hydrolysis ✓	2(AO 1.1)(AO 2.5)	DO NOT ALLOW Polyetser DO NOT ALLOW Hydration
		ii	permanent dipole – permanent dipole ✓ difference in electronegativity between C and O cause permanent dipole to be present AW ✓	2(AO 2.1 x2)	ALLOW omission of one 'permanent' but not abbreviations ALLOW 'O is more electronegative than C' / implied if C, O δ^+ δ^- electronegative point is implied DO NOT ALLOW general references to electronegativity e.g. Oxygen has a high electronegativity - must be compared to C <u>Examiner's Comments</u> The most common mistake made by a significant number of candidates in this question was to suggest hydrogen bonding was the strongest type of intermolecular bonding between the PLA polymer chains.

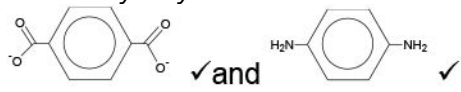
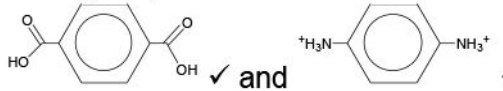
Mark Scheme

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	c		1. Adsorption of reactant(s) (molecules) on catalyst surface 2. Bonds break (within reactants/ intramolecular bonds break) 3. <u>New</u> bonds form 4. Desorption/diffusion/release off surface of catalyst of product(s) (molecules)/leaves catalyst surface All correct 2 marks ✓✓ Three correct 1 mark ✓	2(AO 1.1 x2)	ALLOW reactants/molecules form bonds with <u>surface of catalyst</u> DO NOT allow catalyst adsorbed to reactant's surface Ignore bonds weaken DO NOT allow bonds between reactants/intermolecular bonds Don't worry about where <u>new</u> bonds form Ignore references to activation energy If discussion in terms of enzymes – max 1 mark Remember not ticks for each step – colour dot <u>Examiner's Comments</u> The most common error in answers to this question was to suggest that bonds <u>between</u> reactants (i.e. intermolecular bonds), rather than bonds <u>within</u> reactants (intramolecular bonds), were broken in step 2.
			Total	9	

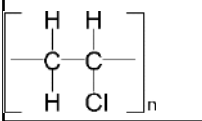
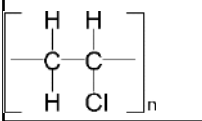
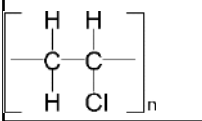
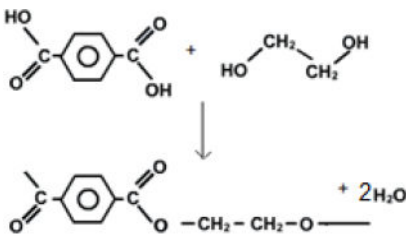
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
70	a		A: (di)acyl chloride ✓ B: (di)amine ✓	2 (AO1.1 x 2)	IGNORE arene/benzene/aromatic ring/secondary/ DO NOT ALLOW phenyl/amide/acyl on its own <u>Examiner's Comments</u> This was a good question to get candidates' confidence raised, most candidates correctly identified that A contained an acyl chloride functional group, and that B contained an amine functional group. The terms primary or secondary were ignored when marking this question. Some candidates also included the benzene ring in both compounds. The only commonly seen incorrect response was the identification of the NH₂ group as an amide group.
	b	i	Heat/ reflux with HCl / H ₂ SO ₄ / NaOH / acid / alkali / names ✓	1(AO1.2)	DO NOT ALLOW conc. H₂SO₄ <u>Examiner's Comments</u> There were two possible routes that candidates could have identified for carrying out the procedure in the question. So there was scope for errors to be made that needed to be accounted for in the mark scheme. In (i) we were looking for the reagents AND reaction conditions necessary to bring about the hydrolysis reaction. For this, what was required was a solution of (moderately concentrated) acid or alkali and heat/reflux. The strength of the acid or alkali was not required but it is worth noting that the use of concentrated sulfuric acid was not allowed, as this would have dehydrated the polymer rather than hydrolysing it. Then in (ii) we hoped that candidates would be able to draw appropriate diagrams to illustrate the products of their hydrolysis reaction. As with 1(e)(i) and (ii) there was a route that gave candidates 1 mark in (ii) for drawing correct structures of both of the unionised products of the hydrolysis reaction.

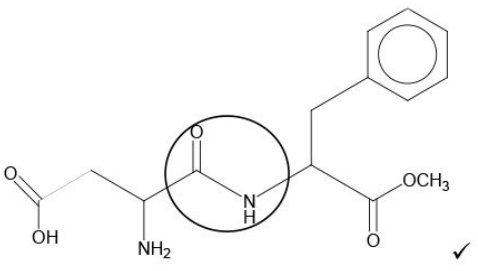
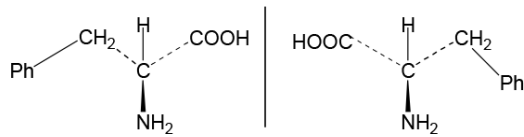
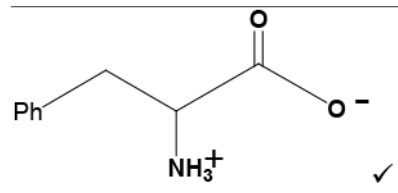
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Answer depends on catalysts chosen in (i): alkaline hydrolysis:  acid hydrolysis: 	2(AO1.2 x 2)	ALLOW salts rather than cation/ anion ALLOW any unambiguous representation ALLOW one mark for unionised diamine and dicarboxylic acid IGNORE ambiguous attachments eg OH attached through H
			Total	5	
71			phenol ✓ (secondary) amide ✓	2(AO 1.2 x2)	ALLOW hydroxyl group NOT alcohol <u>Examiner's Comments</u> This question was generally well answered by a majority of candidates. The most common errors seen included 'alcohol', rather than 'phenol', and 'amine' rather than 'amide'.
			Total	2	
72			A	1 (AO1.2)	
			Total	1	
73			A	1 (AO1.2)	
			Total	1	
74			A	1 (AO1.1)	
			Total	1	
75			D	1 (AO1.2)	
			Total	1	
76			C	1 (AO1.2)	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance				
77	a		<table border="1"><tr><td>Repeat unit</td><td>Type of polymerization</td></tr><tr><td></td><td>Addition</td></tr></table> ✓ ✓	Repeat unit	Type of polymerization		Addition	2 (AO1.2)	IGNORE brackets and 'n'.
Repeat unit	Type of polymerization								
	Addition								
	b	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.				
			Total	6					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
78	a			1 (AO1.1)	ALLOW correct C–N bond circled Examiner's Comments This was generally completed fully by most candidates with very few instances of sub-sections not being attempted. In this part the most commonly seen error was in identifying the amide group as the -NH- (or -NH₂) group and omitting the C=O group.
	b	i	 Correct 3D structure around chiral centre ✓ correct mirror image ✓	2 (AO2.1 ×2)	ALLOW any object and correct mirror image scores 1 mark ALLOW dotted wedges instead of dotted lines. ALLOW wedges for bonds in front of the plane of the paper ALLOW two ordinary lines as long as they are not 180° to each other.
		ii		1 (AO1.1)	DO NOT ALLOW NH³⁽⁺⁾ IGNORE extra correct details on skeletal structure

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$\text{H}_2\text{NCH}(\text{COOH})\text{CH}_2\text{COOH}$ also formed ✓ also CH_3OH ✓ hydrolysis of ester ✓	3 (AO3.2 × 3)	ALLOW any unambiguous structures ALLOW NH_3^+ in formula of amino acid <u>Examiner's Comments</u> In part (iii) few candidates scored more than 1 mark as they did not recognise that aspartame contains an ester as part of its structure; any hydrolysis reaction of the molecule would also result in the hydrolysis of the ester producing methanol as a further product of the reaction. However, when it came to describing the practical technique used to identify the products of hydrolysis, chromatography, this was very well answered and demonstrated that candidates had used this technique within the required practical element of the course.
	c		Instantaneous (dipole)-induced dipole / id-id ✓	1 (AO2.5)	ALLOW Van der Waals or London
	d	i	place in solvent and allow solvent to rise up paper ✓ solvent below level of spot ✓ (dry and) use ninhydrin / locating agent / UV (light) ✓ more than one spot indicates hydrolysis ✓	4 (AO1.2) (AO3.3) (AO1.2) (AO3.4)	ALLOW labelled diagrams to score MP1, 2 & 4 IGNORE use of water as solvent ALLOW matching spots from individual amino acids
		ii	enzyme would be denatured / tertiary structure broken down so no reaction (AW) ✓	1 (AO3.1)	
		iii	No difference to rate (AW)✓ Aspartame / substrate zero order (when in excess) ✓	2 (AO3.1 × 2)	ALLOW initially rate increases AND then becomes constant(AW) ALLOW all active sites occupied(AW) when aspartame in excess / at high concentration'
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
79		i	guanine✓	1 (AO1.1)	
		ii	hydrogen (bond)✓	1 (AO2.1)	
		iii	(dative) covalent / co-ordinate (bond) ✓ (lone) pair on nitrogen donated to Pt ✓	2 (AO2.1 × 2)	
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
80	a	i	(C=C) decolorises bromine water ✓ (COOH / acid) will fizz with carbonate / appropriate colour with (named) indicator ✓	2 (AO1.2 × 2)	ALLOW gas produced turns limewater cloudy(AW) if carbonate test used Examiner's Comments In part (i) and (ii) most candidates scored 3 or 4 marks, usually missing the final conversion from amount of NaOH to volume of NaOH by failing to include the reaction stoichiometry in their calculation.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 5 (cm ³) award 3 marks conc maleic acid = (2.32/116) OR 0.02 (mol dm ⁻³) ✓ amt NaOH = 2 × 250 × 0.02/1000 OR 0.01 (mol) ✓ vol NaOH = 1000 × 0.01/2 = 5	3 (AO2.4 × 3)	2.5 scores 2 marks ALLOW ecf Allow wrong answers (after ecf) to 2 or more sig figs.
	b	i	CHO ✓	1 (AO1.2)	ALLOW elements in any order
		ii	Z ✓ butenedioic acid ✓	2 (AO1.1 × 2)	ALLOW 'butendioic acid'
	c		Loss of COOH / CO ₂ H OR C ₃ H ₃ O ₂ ⁽⁺⁾ /CHCHCOOH✓	1 (AO2.6)	

Mark Scheme

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	d		<i>Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.</i> Level 3 (5 – 6 marks) Correct structure / identity deduced and detailed evidence related to the structure is provided from each spectrum. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Correct structure / identity deduced with detailed evidence from at least one spectrum. OR Structure / identity attempted with some correct evidence from a minimum of two spectra. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Correct structure / identity deduced with no relevant evidence. OR Structure / identity not given or incorrect, but some correct evidence from at least one spectrum. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or nothing of value	6 (AO3.1 × 4) (AO3.2 × 2)	Indicative scientific points may include: AO3.1 Analysis: IR: • C=O at 1700 • Broad OH 2500-3300 • COOH HNMR: • Three H environments • 1.2: Hs on C connected to C-H • 2.3: H on C connected to Cs with many Hs • 11.8 H in COOH CNMR: • Three C environments • two Cs in same environment • one C=O (at 183ish) • two C-C AO3.2 Evaluation: Compound A identified as 2-methylpropanoic acid Structure CH₃CH(CH₃)COOH presented in any unambiguous way
			Total	15	

Mark Scheme

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