PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 5: ORGANIC NITROGEN COMPOUNDS

SCORE	PERCENTAGE
/144	%

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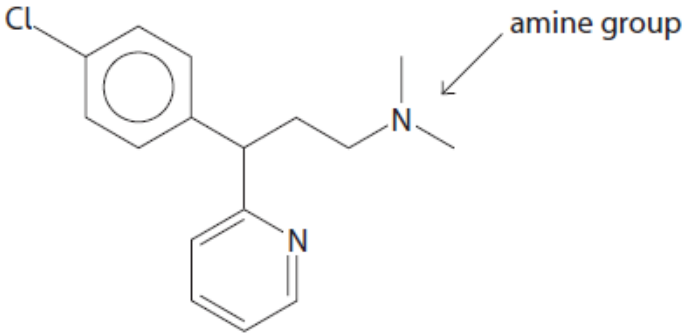
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Q1.

Chlorpheniramine is an amine used in the treatment of hayfever.

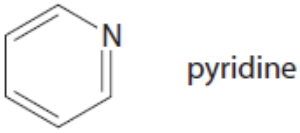


(a) Deduce the classification of the labelled amine group.

(1)

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(b) The compound pyridine is used in the synthesis of chlorpheniramine.



Like many amines, pyridine is miscible with water and the solution formed is alkaline.

Explain **each** of these properties of pyridine.

(4)

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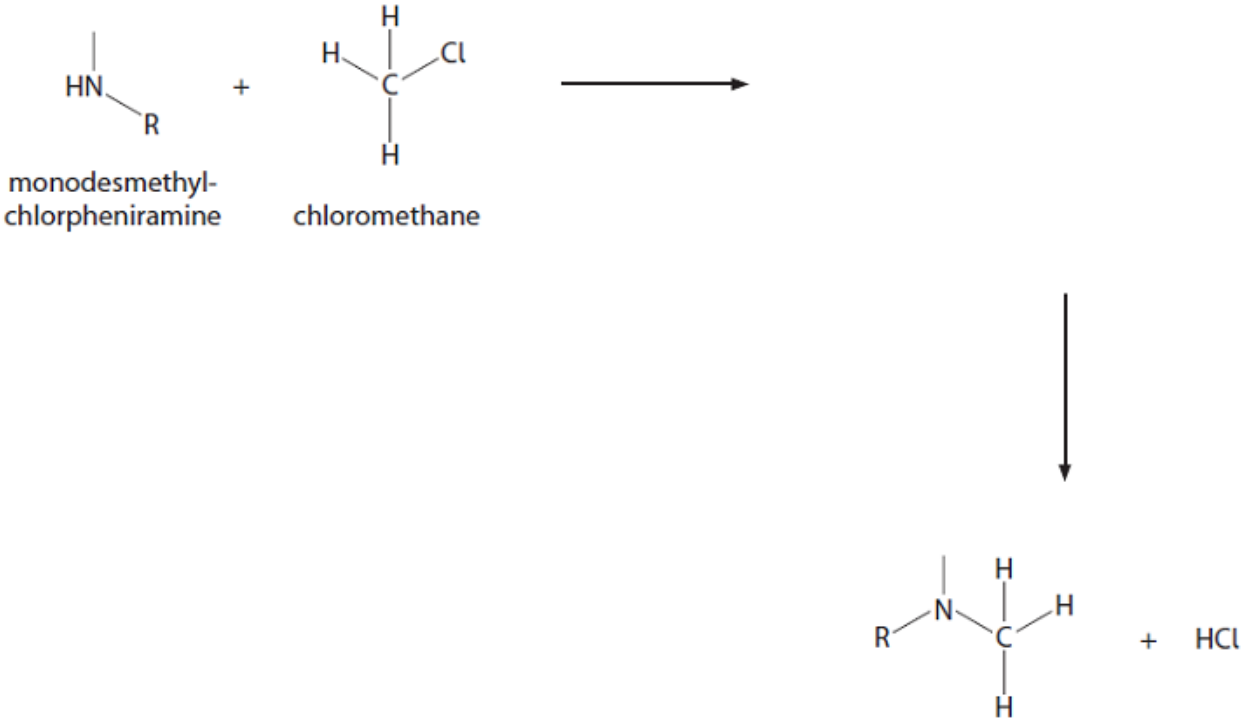
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(c) A student suggested that the final step in the synthesis of chlorpheniramine starts with the reaction between monodesmethylchlorpheniramine and chloromethane.

Assuming the reaction is similar to that between ammonia and chloromethane, complete the mechanism for this proposed reaction.
Some of the organic structures shown have been simplified.

Include curly arrows, and any relevant dipoles and lone pairs of electrons.

(4)



(Total for question = 9 marks)

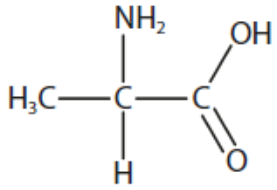
Q2.

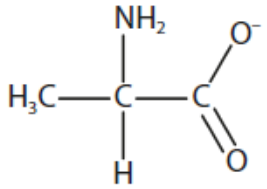
Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

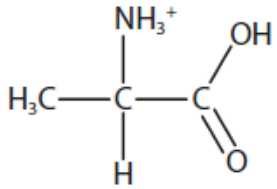
Alanine is an amino acid.

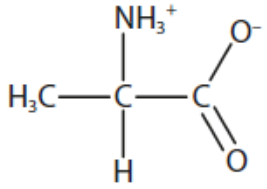
(a) Which structure best represents alanine at **high** pH?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(b) Alanine is a crystalline solid at room temperature.

What are the main forces broken when alanine melts?

(1)

☒ **A** London forces

☒ **B** hydrogen bonds

☒ **C** covalent bonds

☒ **D** ionic bonds

(Total for question = 2 marks)

Q3.

This question is about the investigation of an organic compound **X**.
X is a liquid at room temperature and pressure, which turns damp red litmus paper blue.

(a) (i) Name the functional group present in **X**.

(1)

.....

(ii) When 0.493 g of **X** was vaporised, 157 cm^3 of dry air was displaced, measured at 15°C and 103 000 Pa.

Calculate the molar mass of **X**, using the ideal gas equation.
You **must** show your working.

(4)

(b) **X** reacted vigorously with ethanoyl chloride forming steamy fumes and a white solid **Y**.

(i) Identify the steamy fumes, by name or formula.

(1)

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.....

(ii) Suggest the functional group present in **Y**.

(1)

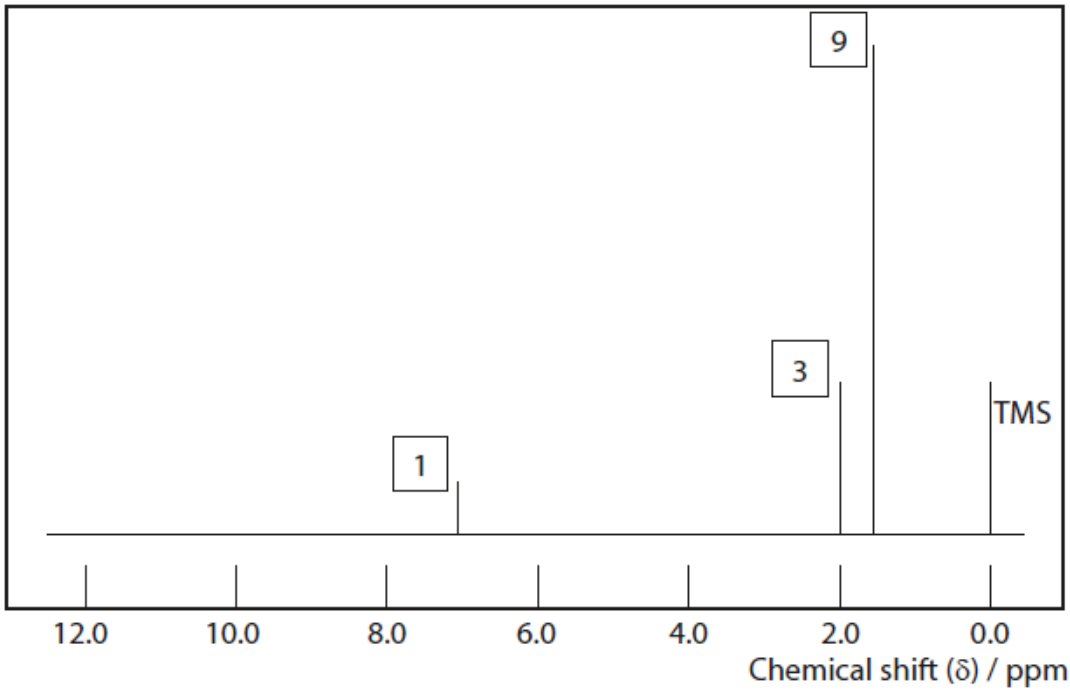
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(iii) Analysis of **Y** showed that its composition by mass was 62.6 % carbon; 11.3 % hydrogen; 12.2 % nitrogen; 13.9 % oxygen.

Determine the empirical formula of **Y**. You **must** show your working.

(3)

*(c) A simplified **high** resolution proton NMR spectrum of **Y** is shown.
The relative peak areas are given near each peak.



Deduce the structure of **Y**, using the NMR spectrum and the other information in the question.

(6)

(d) Draw the structure of compound **X**.

(1)

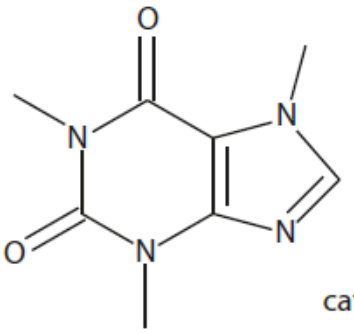
(Total for question = 17 marks)

Q4.

Coffee Chemistry

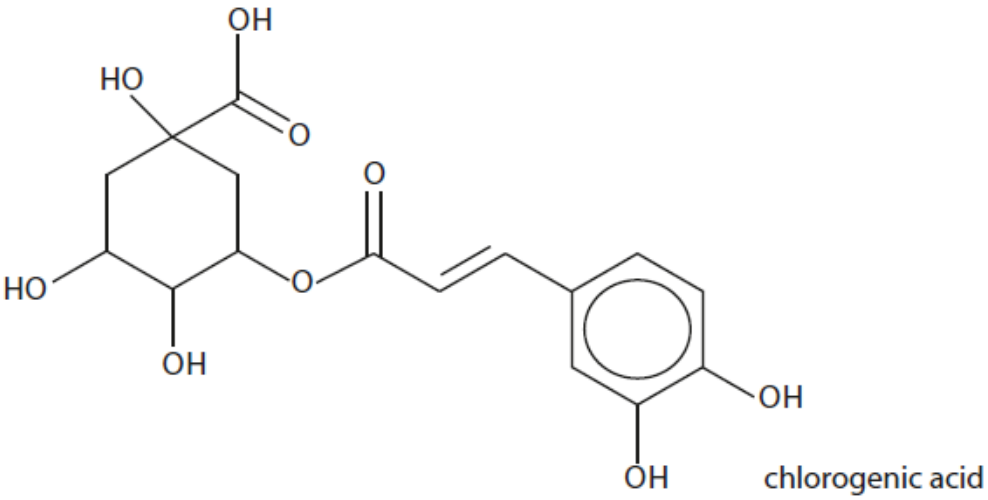
There are over a thousand chemical compounds in coffee and their physiological effects are the subject of considerable speculation and research. The verdict on coffee is contradictory: some of the compounds have been identified as toxic and even carcinogenic but others are antioxidants associated with cancer prevention. Recent research has identified compounds in coffee that might be used in the treatment of prostate cancer.

By far the best known compound in coffee is caffeine, the most widely consumed psychoactive drug in the world. In small amounts it is a stimulant but doses in excess of 10 g per day are toxic. Caffeine contains amide and amine groups.



caffeine

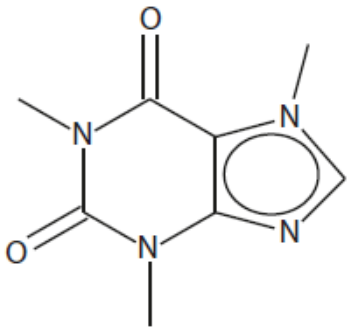
Chlorogenic acid is responsible for the acidic taste of coffee. It is an antioxidant and has also been shown to slightly decrease blood pressure.



chlorogenic acid

Caffeic acid, quinic acid and acetoin are also present in coffee.

(a) Another way of drawing the structure of caffeine is shown.



(i) The bonding represented by this diagram of caffeine differs from that given in the passage.

Explain what this diagram indicates about the bonding in caffeine, stating the effect on the structure of caffeine.

(3)

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(ii) Suggest why caffeine is a much weaker base than a primary amine such as ethylamine, even though the right-hand ring has two amine groups.

(2)

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(b) A 200 cm^3 cup of coffee contains approximately 85 mg of caffeine.

(i) Calculate the concentration, in mol dm^{-3}, of caffeine in this cup of coffee.
Give your answer to an appropriate number of significant figures.

(4)

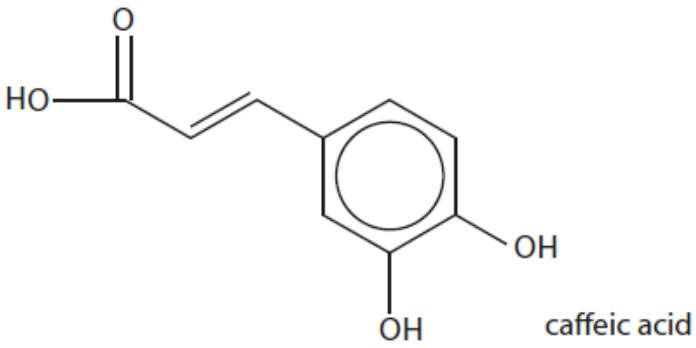
(ii) The removal of caffeine from the body is a first order reaction with a half-life of between three and seven hours for an adult.

An adult drinks coffee containing a total of 160 mg of caffeine.

Calculate to the nearest hour the **minimum** time needed for the amount of caffeine in their body to drop to 20 mg.

(2)

(c) Chlorogenic acid is an ester of caffeic acid, a compound that is present in all plants.



caffeic acid

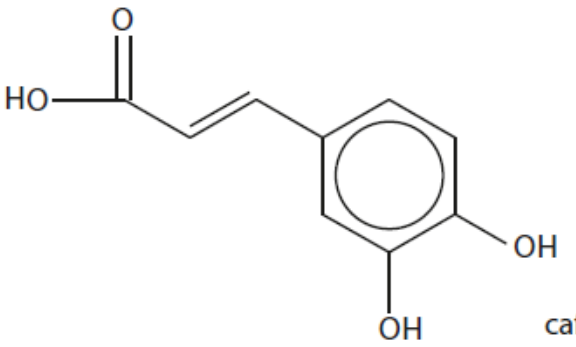
(i) A student suggested that caffeic acid could be synthesised by an electrophilic substitution of 1,2-dihydroxybenzene.

Draw the mechanism of this electrophilic substitution, including the formation of a suitable electrophile.

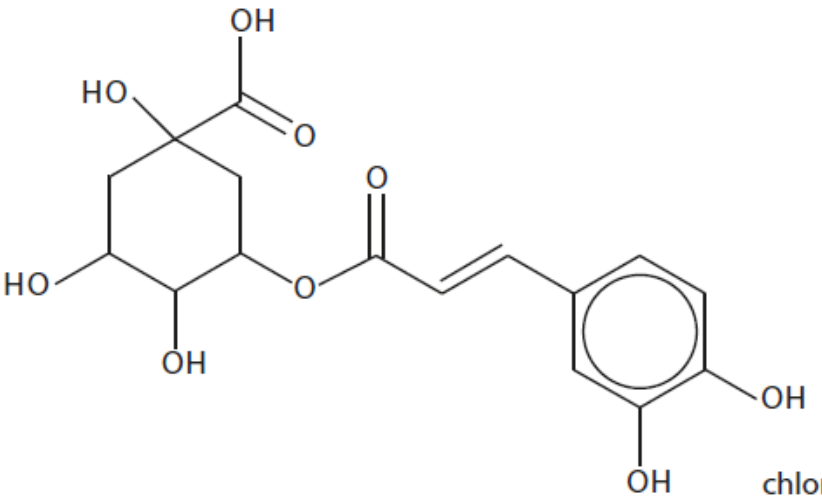
(5)

(ii) Deduce the structure of quinic acid which combines with caffeic acid to form chlorogenic acid.

(1)



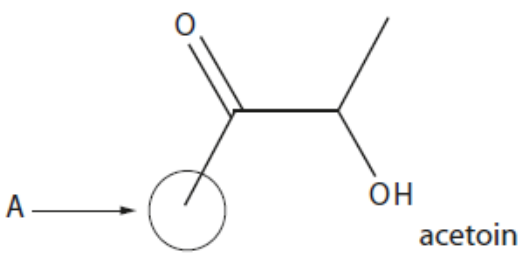
caffeic acid



chlorogenic acid

quinic acid

(d) The structure of acetoin is shown with one of the proton environments labelled.



acetoin

(i) Identify the other proton environments of acetoin on the structure and label them B, C etc.

(1)

(ii) Complete the table to show the splitting pattern in the high resolution proton NMR spectrum of acetoin.

(2)

Proton environment	Splitting pattern
A	

(Total for question = 20 marks)

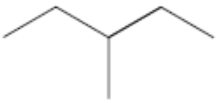
Q5.

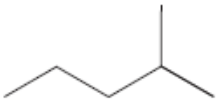
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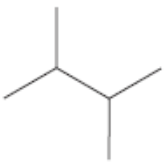
A compound with the formula C_6H_{14} gives a ^{13}C NMR spectrum with four peaks.

Which compound gives this spectrum?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for question = 1 mark)

Q6.

Identify the correct trend of **increasing** strength as a base.

(1)

☒ **A** $C_6H_5–NH_2 < H–NH_2 < CH_3–NH_2$

☒ **B** $C_6H_5–NH_2 < CH_3–NH_2 < H–NH_2$

☒ **C** $H–NH_2 < CH_3–NH_2 < C_6H_5–NH_2$

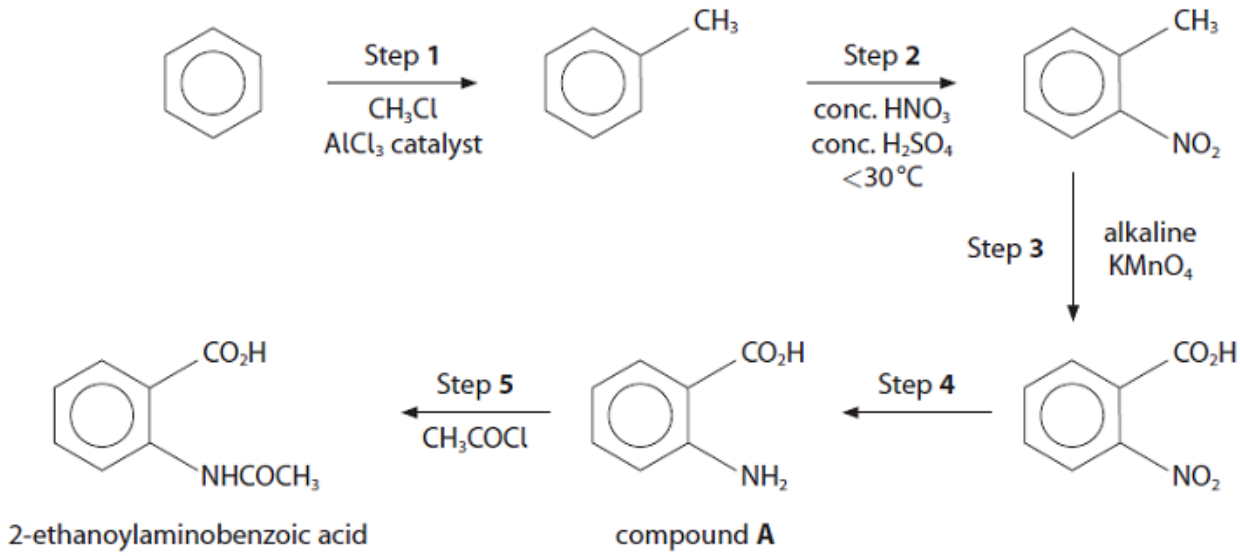
☒ **D** $H–NH_2 < C_6H_5–NH_2 < CH_3–NH_2$

(Total for question = 1 mark)

Q7.

This question is about 2-ethanoylaminobenzoic acid.
Crystals of this compound emit flashes of light when crushed.

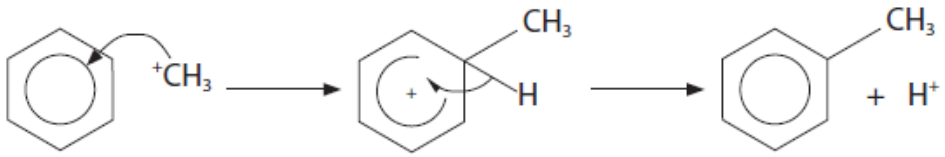
2-ethanoylaminobenzoic acid can be synthesised using benzene as a starting material.



(a) A student proposed a mechanism for Step 1.

(a) A student proposed a mechanism for Step 1.

$$CH_3Cl + AlCl_3 \longrightarrow {}^{+}CH_3 + AlCl_4^-$$



$$H^+ + AlCl_4^- \longrightarrow HCl + AlCl_3$$

(i) Identify **two** errors in the mechanism by circling them.

(2)

(ii) State how the errors identified in (a)(i) should be corrected. Justify your answer in terms of the structures involved.

(2)

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(b) Give a reason why it is important to keep the temperature below 30 °C in Step **2**.

(1)

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(c) State the type of reaction in Step **3**.

(1)

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(d) Identify, by name or formula, the reagents needed for Step **4**.

(1)

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(e) Explain how the structures of ethanoyl chloride, CH_3COCl, and compound **A** enable them to react forming 2-ethanoylaminobenzoic acid in Step **5**.

(3)

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(f) Calculate the volume of benzene required to form 5.92 g of 2-ethanoylaminobenzoic acid, assuming the overall yield for the synthesis is 28.2 %.

Give your answer to an appropriate number of significant figures.

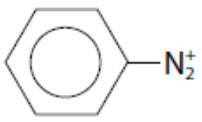
[Density of benzene = 0.879 g cm^{-3}]

(4)

(Total for question = 14 marks)

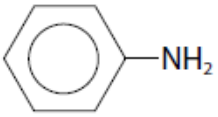
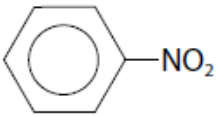
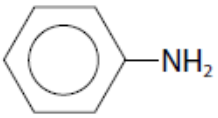
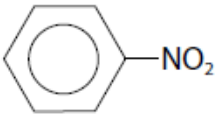
Q8.

Azo dyes are made from the benzenediazonium ion.



(a) Benzenediazonium ions can be made from:

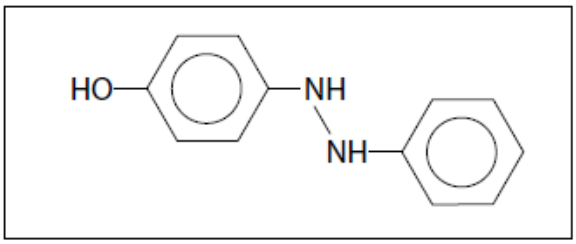
(1)

	Reagent 1	Reagent 2
☒ A	HNO_2	
☒ B	HNO_2	
☒ C	HNO_3	
☒ D	HNO_3	

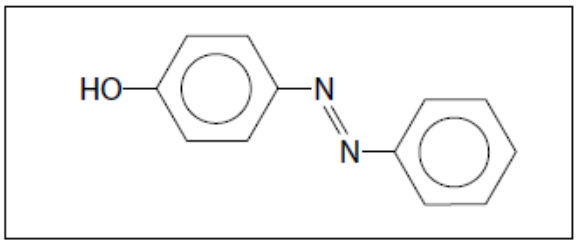
(b) The structure of the azo dye formed when benzenediazonium ions react with phenol is

(1)

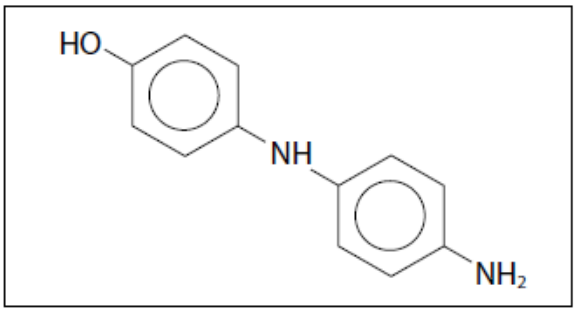
☒ **A**



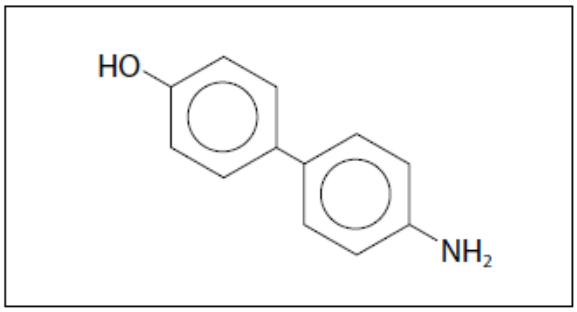
☒ **B**



☒ **C**



☒ **D**



(Total for question = 2 marks)

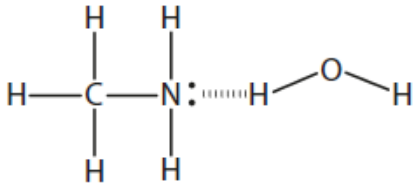
Q9.

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

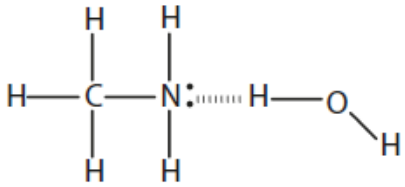
Hydrogen bonds are formed when methylamine dissolves in water.

Which structure best represents a hydrogen bond between methylamine and water?

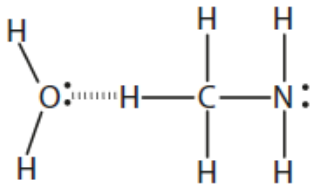
☐ **A**



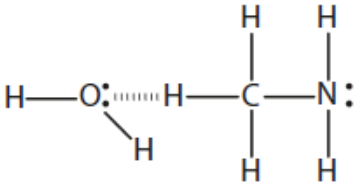
☐ **B**



☐ **C**



☐ **D**

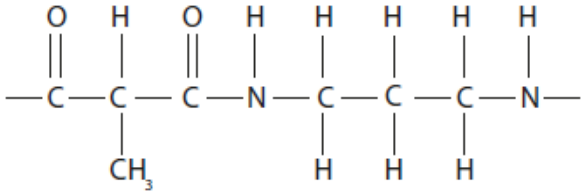


(Total for question = 1 mark)

Q10.

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

The repeat unit of a polymer is shown.



This polymer could be

☒ **A** both a polypeptide and a polyamide

☒ **B** neither a polypeptide nor a polyamide

☒ **C** a polypeptide but not a polyamide

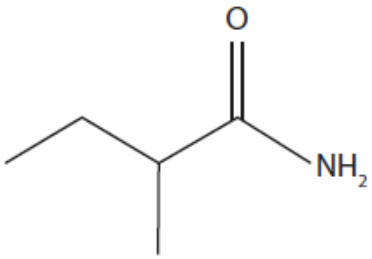
☒ **D** a polyamide but not a polypeptide

(Total for question = 1 mark)

Q11.

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

What is the name of the compound shown?



☒ **A** 1-methylpropanamide

☒ **B** 3-methylpropanamide

☒ **C** 2-methylbutanamide

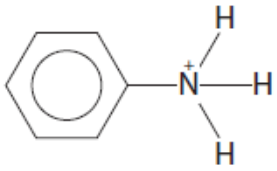
☒ **D** 3-methylbutanamide

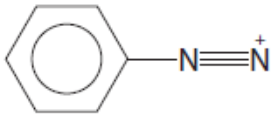
(Total for question = 1 mark)

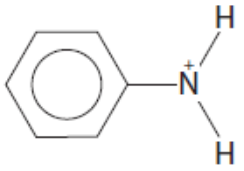
Q12.

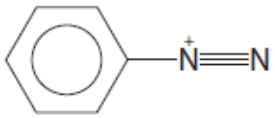
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which ion is formed when a mixture of sodium nitrite, $NaNO_2$, and dilute hydrochloric acid reacts with phenylamine at a temperature of 5°C?

☐ **A** 

☐ **B** 

☐ **C** 

☐ **D** 

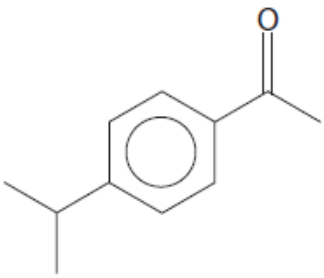
Use this space for rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q13.

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

Cuminone is used as a flavouring.



cuminone

What is the molecular formula of cuminone?

☒ **A** $C_{10}H_{13}O$

☒ **B** $C_{10}H_{15}O$

☒ **C** $C_{11}H_{14}O$

☒ **D** $C_{11}H_{16}O$

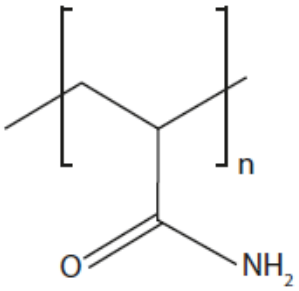
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(Total for question = 1 mark)

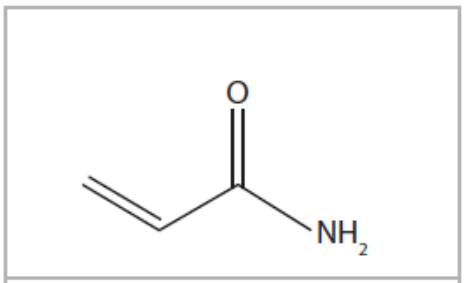
Q14.

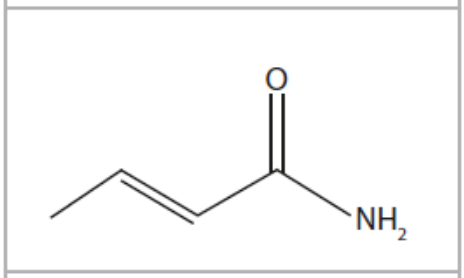
Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

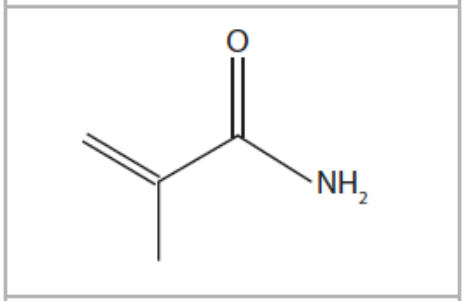
The repeat unit of a polymer is shown.

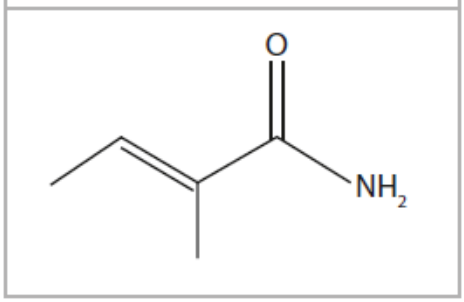


What is the structure of the monomer?

☒ A 

☒ B 

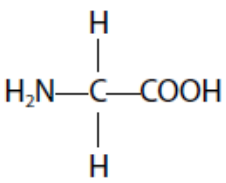
☒ C 

☒ D 

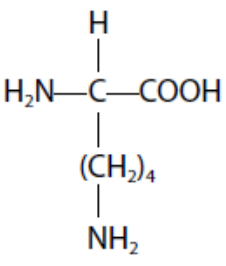
(Total for question = 1 mark)

Q15.

Glycine and lysine are two naturally-occurring amino acids.



glycine



lysine

(a) Write the equation for the reaction of glycine with sodium hydroxide.

State symbols are not required.

(1)

(b) Calculate the volume, in cm^3, of 0.100 mol dm^{-3} hydrochloric acid required to completely react with 1.825 g of lysine.

[M_r of lysine = 146]

(2)

(c) Lysine exists as optically active enantiomers but glycine does not.

(i) Draw three-dimensional diagrams of the two optically active lysine enantiomers.

(2)

(ii) Describe how these optically active enantiomers could be distinguished.

Practical details are not required.

(2)

.....

.....

.....

(iii) State why glycine does not exist as enantiomers.

(1)

.....

.....

.....

(d) Chromatography can be used to separate a mixture of glycine and lysine.

Draw spots to show the location of glycine and lysine on the chromatogram, given that their R_f values are 0.26 and 0.14 respectively.

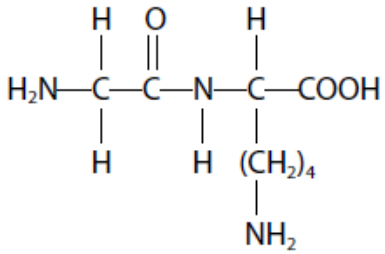
(1)



(e) Naturally-occurring glycine and lysine can join together to form different dipeptides.

Draw a different dipeptide of glycine and lysine.

(1)

Dipeptide 1	Dipeptide 2
	

(Total for question = 10 marks)

Q16.

Answer the question with a cross in the box you think is correct ☒ . If you change

your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Separate 0.1 mol dm^{-3} aqueous solutions of ammonia, butylamine and phenylamine were prepared.

Which of the following sequences shows the solutions in order of **increasing** pH?

☒ **A** butylamine, phenylamine, ammonia

☒ **B** ammonia, butylamine, phenylamine

☒ **C** phenylamine, ammonia, butylamine

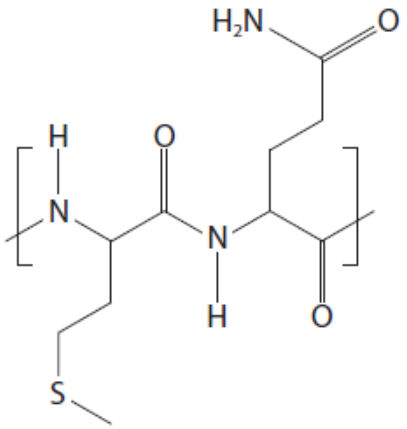
☒ **D** ammonia, phenylamine, butylamine

(Total for question = 1 mark)

Q17.

This question is about polymers.

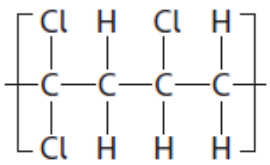
(a) The diagram shows part of the structure of a polymer formed by a **condensation** reaction between two amino acids.



Predict the structures of the two monomers that produce this polymer.

(2)

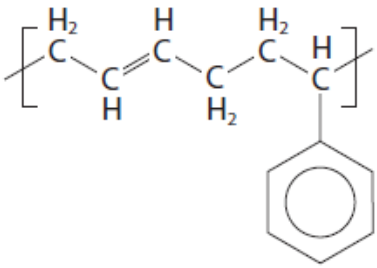
(b) The diagram shows a repeat unit of an addition polymer used in some food wraps. It is formed from two different monomers.



Deduce the structures of the two monomers that produce this polymer.

(2)

(c) A synthetic rubber polymer has the structure shown.



The molar mass of the synthetic rubber is approximately 300 000 g mol^{-1}.

Calculate the approximate number of repeat units in the polymer.

(2)

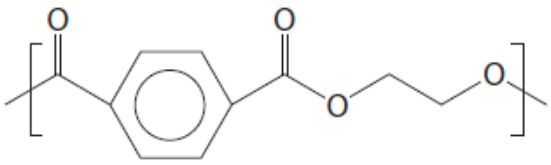
(Total for question = 6 marks)

Q18.

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

This question is about polymers.

(a) A repeat unit of the polymer PET has the structure shown.



What is the percentage by mass of carbon in the repeat unit?

(1)

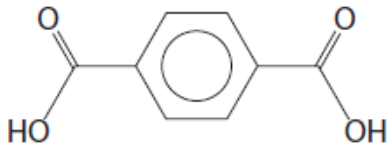
☐ **A** 57.1 %

☐ **B** 62.5 %

☐ **C** 65.2 %

☐ **D** 66.7 %

(b) One of the monomers used to make PET is benzene-1,4-dicarboxylic acid.



How many peaks are there in the 13C NMR spectrum of benzene-1,4-dicarboxylic acid?

(1)

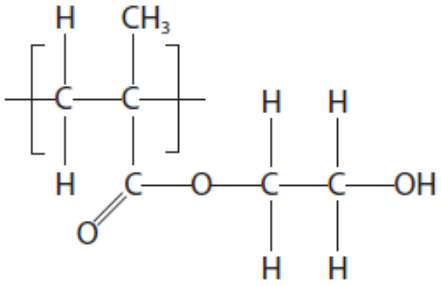
☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 6

(c) The repeat unit of another polymer has the structure shown.



This polymer is formed from

(1)

☒ **A** a single type of monomer by an addition reaction

☒ **B** a single type of monomer by a condensation reaction

☒ **C** two different types of monomer by an addition reaction

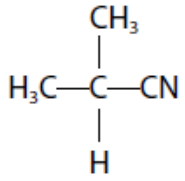
☒ **D** two different types of monomer by a condensation reaction

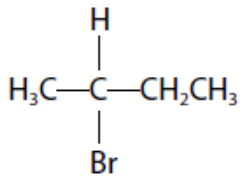
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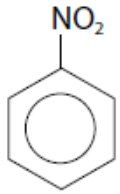
(Total for question = 3 marks)

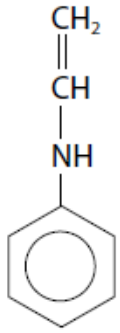
Q19.

Which combination of reactants will produce a primary aliphatic amine as the product?

☒ **A**  + Ni/H_2

☒ **B**  + CH_3NH_2

☒ **C**  + Sn + conc HCl

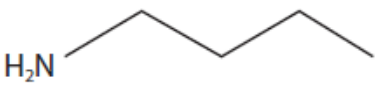
☒ **D**  + Ni/H_2

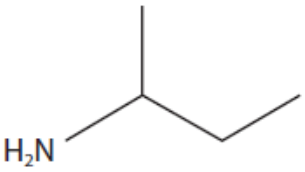
(Total for question = 1 mark)

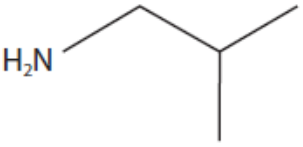
Q20.

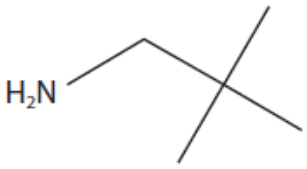
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which amine could **not** be prepared by the reduction of a nitrile?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for question = 1 mark)

Q21.

Which equation shows the two compounds that react to produce ethanamide, CH_3CONH_2, in a single step?

(1)

☒ **A** $CH_4 + HCONH_2 \rightarrow CH_3CONH_2 + H_2$

☒ **B** $CH_3COOH + NH_3 \rightarrow CH_3CONH_2 + H_2O$

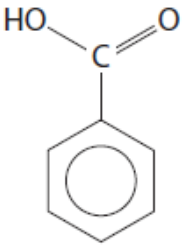
☒ **C** $CH_3COCl + NH_3 \rightarrow CH_3CONH_2 + HCl$

☒ **D** $CH_3CHO + NH_3 \rightarrow CH_3CONH_2 + H_2$

(Total for question = 1 mark)

Q22.

Benzoic acid is a white crystalline solid with the structure shown.



It is found in many plants as it is an important building block for the biosynthesis of a variety of compounds, such as plant hormones and attractants for pollinators.

The role of benzoic acid in the chemical industry is also widespread and approximately 500 000 tonnes are produced annually. It is used in the synthesis of many compounds, including medicines, dyes and insect repellents.

Such synthetic dyes are often classified as aryl azo dyes. These dyes have a range of vivid colours and a wide range of uses in many industries, including food and textiles. Their synthesis involves the formation of a diazonium ion. This ion then reacts with a phenol in a coupling reaction, to form the dye. The relative simplicity of the reactions involved and ready availability of starting materials make azo dyes cheap to produce.

Salts of benzoic acid, such as calcium benzoate and sodium benzoate, are used in the food industry as preservatives.

(a) Devise a reaction scheme to produce benzoic acid from benzene, via bromobenzene and then a Grignard reagent.

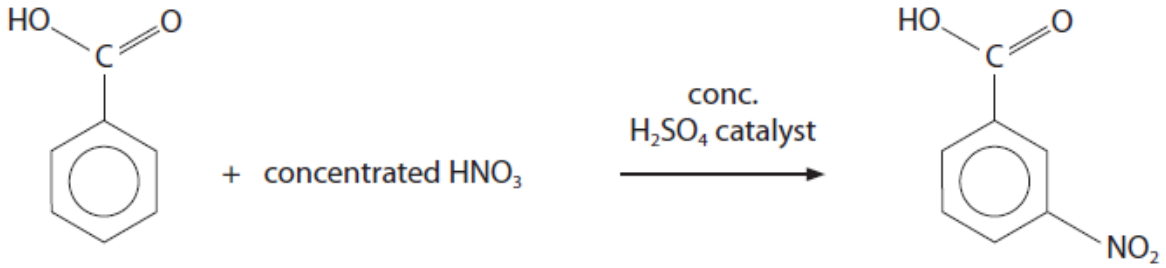
Include the reagents and essential conditions for each step and give the name or structure of each of the intermediate compounds.

Details of practical procedures and reaction mechanisms are **not** required.

(6)

(b) Benzoic acid can be used in the synthesis of azo dyes.

(i) In Step **1**, benzoic acid reacts with concentrated nitric acid to form 3-nitrobenzoic acid.



benzoic acid

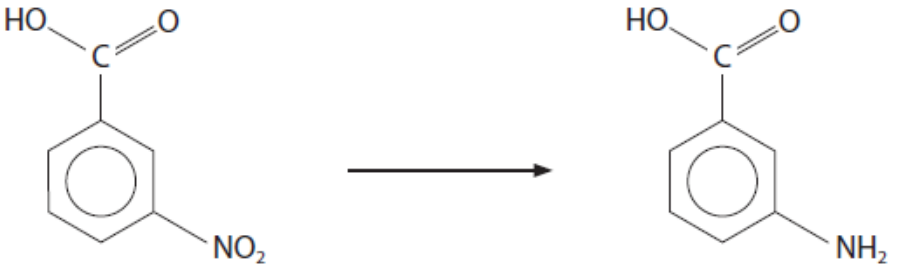
3-nitrobenzoic acid

Draw the mechanism for the reaction, using appropriate curly arrows.

Include equations showing the role of the catalyst and how it is regenerated.

(5)

(ii) In Step **2**, the 3-nitrobenzoic acid reacts to form 3-aminobenzoic acid.



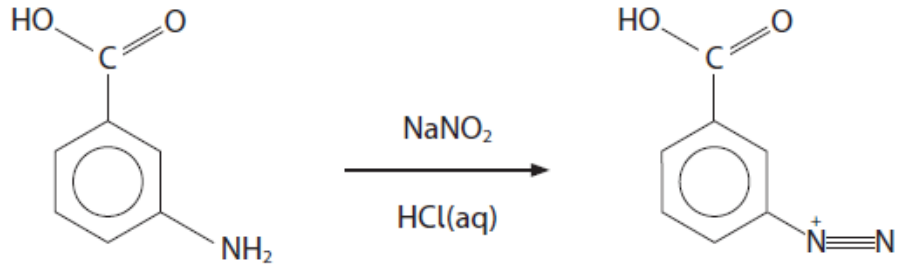
3-nitrobenzoic acid 3-aminobenzoic acid

State the reagents required for this reaction.

(1)

.....

(iii) In Step **3**, the 3-aminobenzoic acid reacts with sodium nitrite and dilute hydrochloric acid, forming a diazonium ion.



3-aminobenzoic acid diazonium ion

State a temperature at which this reaction should take place, giving **one** reason for your answer.

(2)

.....

.....

.....

.....

.....

(iv) Draw the structure of the azo dye formed when the diazonium ion reacts with phenol.

(1)

(c) Hydrated calcium benzoate is used as a preservative in soft drinks. It has the formula $Ca(C_6H_5COO)_2 \bullet xH_2O$.

2.60 g of hydrated calcium benzoate was dissolved in deionised water. Excess lead(II) nitrate solution was added, forming a precipitate of lead(II) benzoate, $Pb(C_6H_5COO)_2(s)$. This precipitate was removed and dried. The mass of the dry solid was 3.89 g.

Calculate the molar mass of hydrated calcium benzoate and hence deduce the value of x.

(6)

(Total for question = 21 marks)

Q23.

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

Which is a redox reaction?

☒ **A** $Cr_2O_7^{2-} + 2C \rightarrow Cr_2O_3 + CO_3^{2-} + CO$

☒ **B** $CrO_2Cl_2 + 4OH^- \rightarrow CrO_4^{2-} + 2Cl^- + 2H_2O$

☒ **C** $Cr_2O_7^{2-} + 2HCl \rightarrow 2CrO_3Cl^- + H_2O$

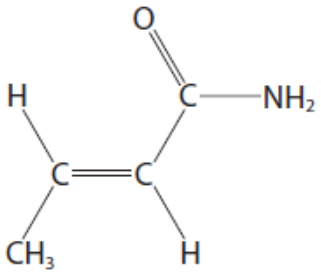
☒ **D** $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$

(Total for question = 1 mark)

Q24.

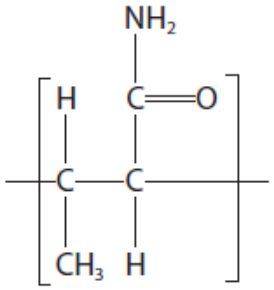
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The structure of crotonamide is shown.

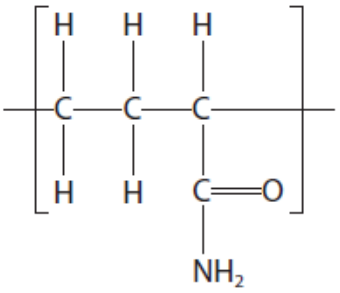


What is the repeat unit of the polymer formed from crotonamide?

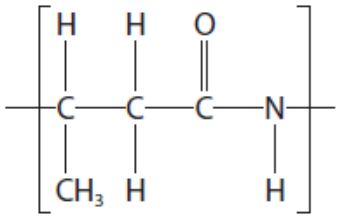
☒ **A**



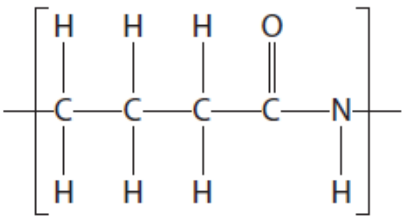
☐ **B**



☐ **C**



☐ **D**

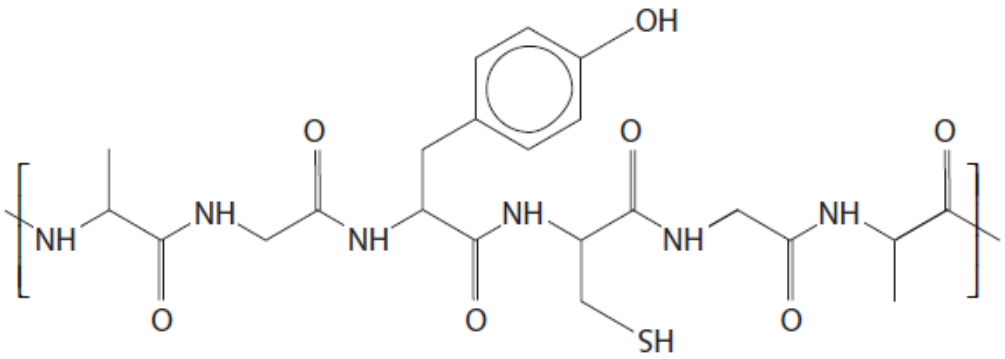


(Total for question = 1 mark)

Q25.

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

How many **different** amino acids form the repeat unit of the polymer shown?



☒ **A** 3

☐ **B** 4

☐ **C** 5

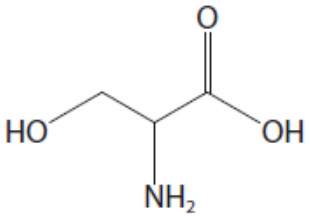
☐ **D** 6

(Total for question = 1 mark)

Q26.

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

This question is about the amino acid serine.

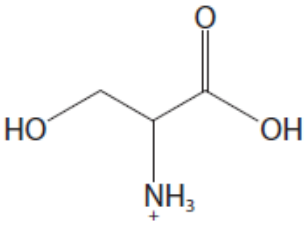


serine

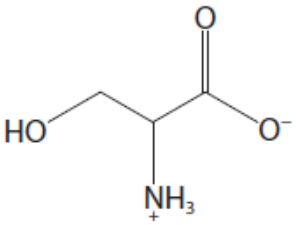
(a) Which ion is most likely to form if serine is dissolved in sodium carbonate solution?

(1)

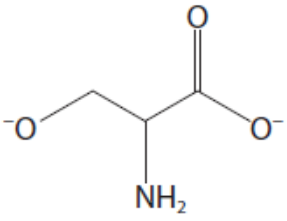
☒ **A**



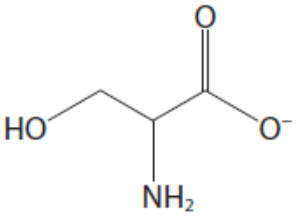
☒ **B**



☒ **C**



☒ **D**



(b) Serine has a melting temperature in the region of 200–300 °C.

This high melting temperature is mainly due to the formation of

(1)

☒ **A** hydrogen bonds

☒ **B** ionic bonds

☒ **C** London forces

☒ **D** peptide bonds

(Total for question = 2 marks)

Q27.

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

Which species contains an element with the same oxidation number as bromine in $KBrO_3$?

☒ **A** N_2O_5

☒ **B** $KMnO_4$

☒ **C** K_2FeO_4

☒ **D** Na_2SO_3

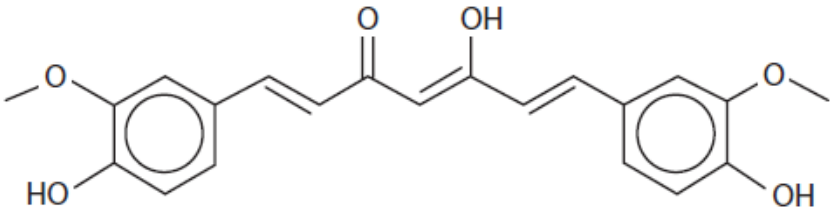
(Total for question = 1 mark)

Q28.

Organic molecules are an important source of colour both in the natural world and in a wide range of industrial applications.

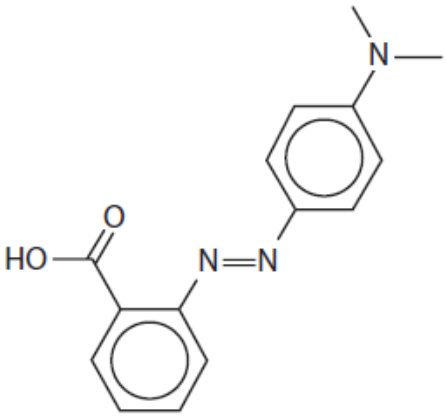
Curcumin contributes to the yellow colour of turmeric spice and is used as an additive in

cosmetics and foods. It has been suggested that curcumin can act as an antioxidant and anticancer agent, through reactions with free radicals and proteins, and may also inhibit Alzheimer's disease by complexing to toxic metal ions.



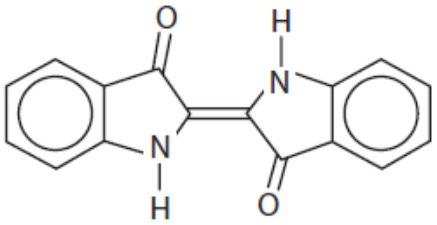
curcumin

Azo dyes are synthetic compounds that do not occur naturally. They can be used to colour textiles such as cotton. The acid-base indicator methyl red is an azo dye.

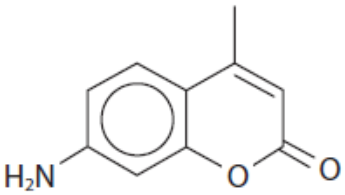


methyl red

Indigotin is used to dye denim a blue colour and coumarin 440 is used to generate blue light in lasers. Both dyes occur naturally in plants but can be synthesised in the laboratory.



indigotin



coumarin 440

(a) The equation shows the reaction between a free radical $T^{\bullet}$ and curcumin (shown by a simplified structure).



curcumin

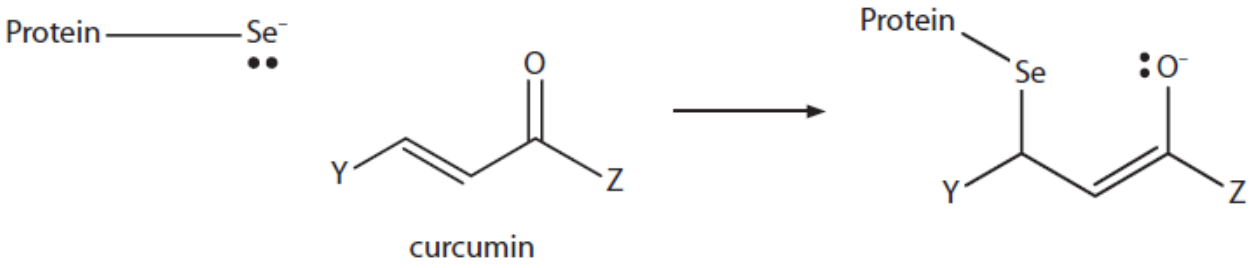
Complete the left-hand side of the equation by adding curly half-arrows.

(1)

(b) Selenide anions attached to protein side-chains may undergo nucleophilic addition reactions with curcumin.

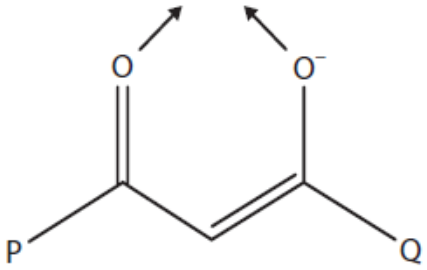
Complete the mechanism for one of the steps in such a reaction, adding curly arrows to the simplified structures shown.

(2)



curcumin

(c) Curcumin anions can act as bidentate ligands in metal-curcumin (M-curc) complexes. The oxygen atoms of the curc ligand occupy adjacent coordination sites in the complex, as shown.



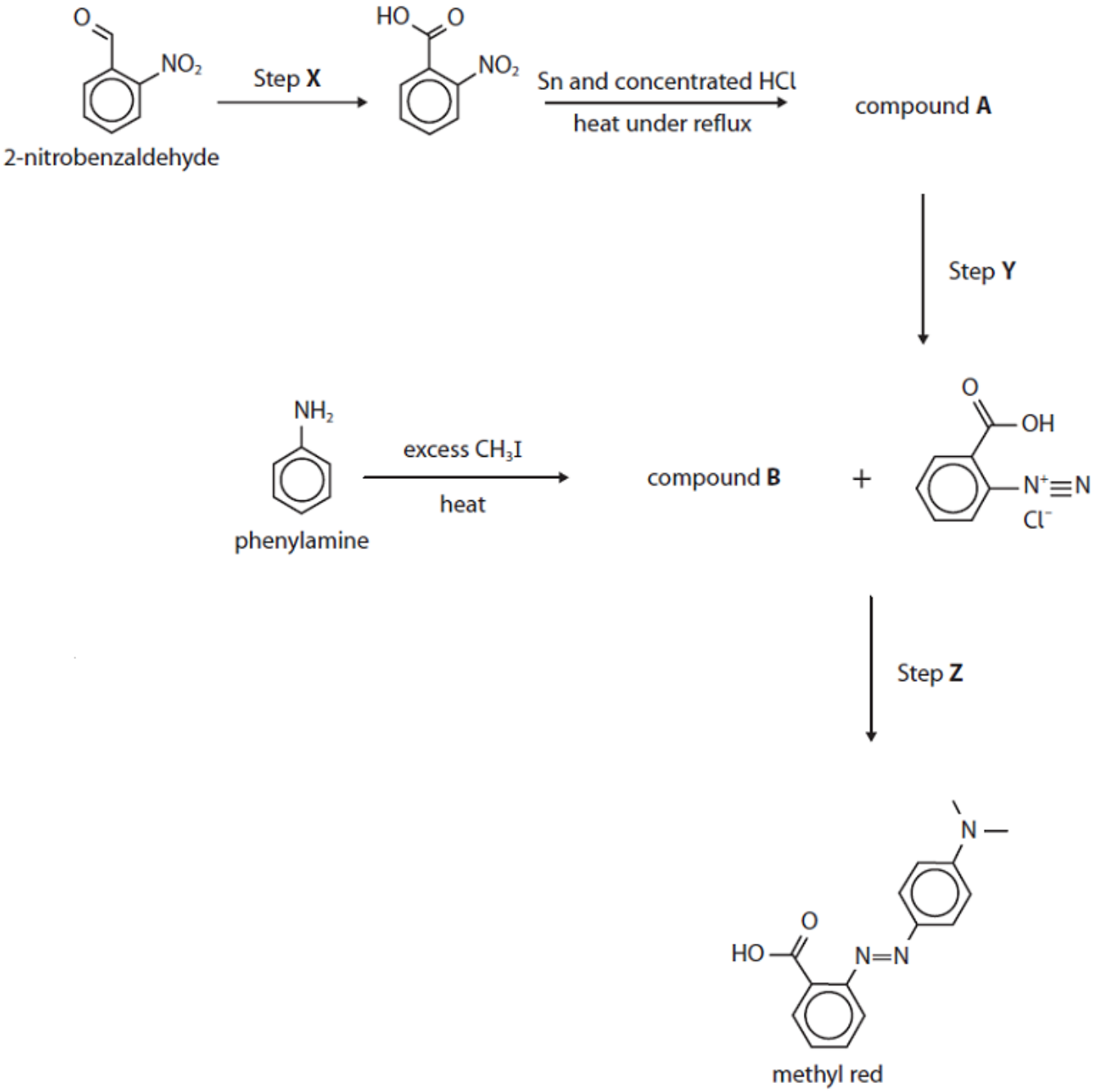
curcumin anion

Complete the table relating to two M-curc complexes.

(2)

	$[Au(curc)_2]^+$	$[Al(curc)(C_2H_5OH)_2(NO_3)_2]$
Coordination number	4	
O—M—O bond angle	90°	
Shape		octahedral
Charge on metal ion		+3

(d) An incomplete synthesis for methyl red starting from 2-nitrobenzaldehyde and phenylamine is shown.



(i) State the reagents and conditions needed in Step **X**.

(2)

.....

.....

(ii) Draw the structure of compound **A**.

(1)

(iii) State the reagents needed in Step **Y**.

(1)

.....

.....

(iv) Draw the structure of compound **B**.

(1)

(v) The temperature used in Steps **Y** and **Z** should be kept as close to 5 °C as possible. State why the temperature should be neither higher nor lower than 5 °C.

(2)

.....

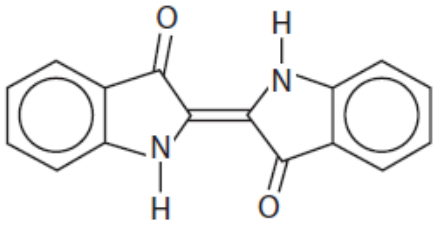
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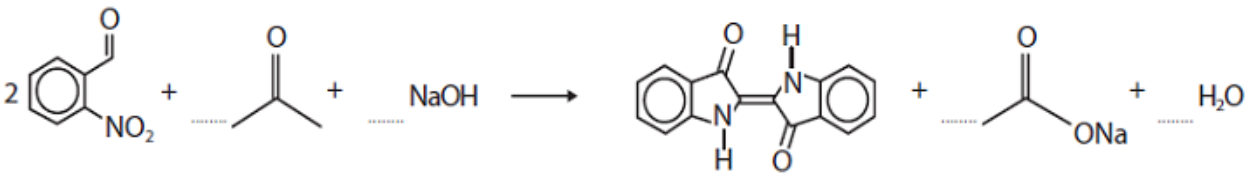
(e) Indigotin can be synthesised from 2-nitrobenzaldehyde and propanone in aqueous sodium hydroxide.



indigotin

(i) Complete the equation for this reaction.

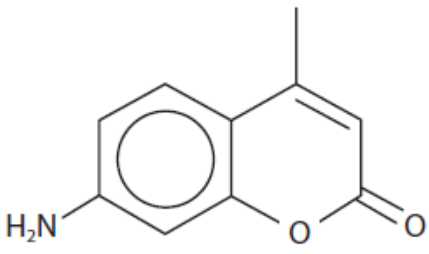
(2)



(ii) Calculate the mass of 2-nitrobenzaldehyde required to make 10.0 g of indigotin from this reaction when the percentage yield is 85.0 %.

(3)

(f) Give the structure of the **organic** product of each of the following reactions of coumarin 440.



coumarin 440

(i) Hydrolysis with **excess** aqueous sodium hydroxide.

(2)

(ii) Condensation with ethanoyl chloride.

(1)

(Total for question = 20 marks)

Q29.

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

When dilute hydrochloric acid is added to butylamine and the solution is allowed to evaporate to dryness, a white solid forms.

What is the formula of the white solid?

☐ **A** $CH_3CH_2CH_2CH_2Cl$

☐ **B** $CH_3CH_2CH_2CH_2NH_3Cl$

☐ **C** $CH_3CH_2CH_2CONH_2$

☐ **D** $CH_3CH_2CH_2COOH$

(Total for question = 1 mark)

Q30.

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

Amines may be prepared by the reduction of nitriles.

Identify the nitrile and the reducing agent used to prepare butylamine.

		Nitrile	Reducing agent
☒	**A**	propanenitrile	lithium tetrahydridoaluminate(III)
☒	**B**	propanenitrile	tin and concentrated hydrochloric acid
☒	**C**	butanenitrile	lithium tetrahydridoaluminate(III)
☒	**D**	butanenitrile	tin and concentrated hydrochloric acid

(Total for question = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

Mark Scheme

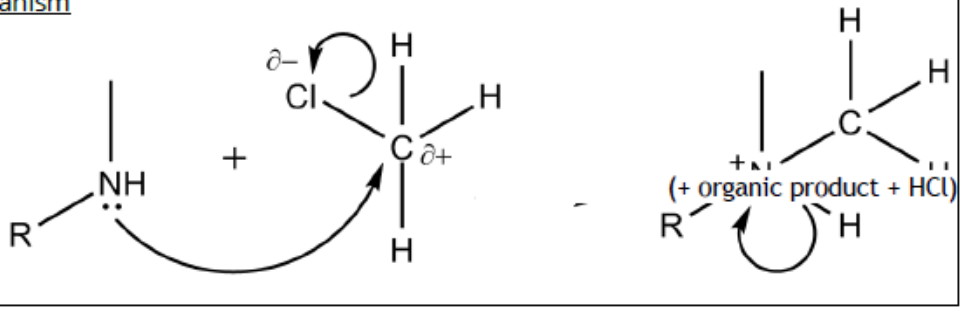
Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• tertiary (amine) / 3° (amine)	Allow tertiary / tertiery / tertiary Do not award '3rd / third (amine) Do not award tertiary amide / 3° amide Ignore attempts to explain classification	**(1)**

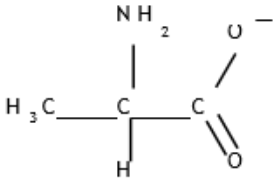
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • the **nitrogen / N** (atom) has a lone pair of electrons **(1)** • which can forms a hydrogen bond to water (to the ∂+ hydrogen) **(1)** • and can accept a H^+ ion (from water) / form $C_5H_5NH^+$ / form a dative bond to a H^+ ion (from water) **(1)** • leaving a (slight excess) of hydroxide ions **(1)**	Mark Independently M1 and M2 can be shown on a diagram Allow '**nitrogen / N** is electronegative (and small)' Allow pyridine can form intermolecular forces with water that are strong enough to overcome the hydrogen bonds in water M3 and M4 can be shown by correct equation $C_5H_5N + H_2O \rightarrow C_5H_5NH^+ + OH^-$	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	An answer that makes reference to the following points • arrow from lone pair on nitrogen atom to carbon atom **(1)** • dipole shown and arrow from C–Cl bond to Cl or just beyond **(1)** • formula of intermediate including the + charge on the N atom **(1)** • arrow from N-H bond to N(+) **(1)**	Allow M1 and M2 via formation of a carbocation Ignore ∂⁻ on N Do not award N^-	**(4)**

Example of mechanism



Q2.

Q	Answer	Mark
(a)	**The only correct answer is B**  ***A*** *is not correct because this structure is only possible near neutral pH* ***C*** *is not correct because this structure is formed at low pH* ***D*** *is not correct because this structure dominates at neutral pH*	**1**

Q	Answer	Mark
(b)	**The only correct answer is D**(ionic bonds) ***A*** *is not correct because van der Waals forces are the weakest forces broken* ***B*** *is not correct because hydrogen bonds are weaker than ionic bonds* ***C*** *is not correct because* covalent bonds are not broken when amino acids melt	**1**

Q3.

Q	Answer	Additional guidance	Mark
(a)(i)	• Amine	Allow amino Ignore classification such as 'tertiary' Ignore NH_2 Do not award ammine	**1**

Q	Answer	Additional guidance	Mark
(a)(ii)	Method 1 • rewrite the Ideal Gas Equation in terms of mass and molar mass(1) • change the subject of the equation (1) • change volume to m^3 **and** temperature to K(1) • calculation of molar mass (1)	Example of calculation $PV = \frac{mRT}{M_r}$ $M_r = mRT/PV$ 157 cm^3 = 1.57 x 10^{-4} / 0.000157 m^3 Allow conversion to kPa & vol to dm^3 15°C = 288 K $M_r = \frac{0.493 \times 8.31 \times 288}{103000 \times 1.57 \times 10^{-4}}$ = 72.963 = 73.0 / 73 (g mol^{-1})	4

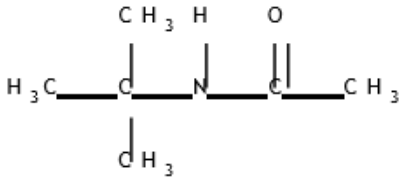
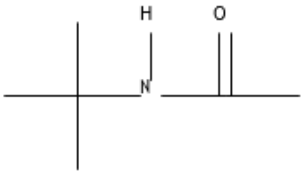
	• Method 2 • Change subject of equation (1) • change volume to m^3 **and** temperature to K (1) • evaluate n (1) • calculation of molar mass (1)	$n = PV/RT$ 157 cm^3 = 1.57 x 10^{-4} / 0.000157 m^3 Allow conversion to kPa & vol to dm^3 n = 103000 x 1.57 x 10^{-4} / 8.31 x 288 =6.7568 x 10^{-3} M_r = 0.493 / 6.7568 x 10^{-3} = 72.963 = 73 (g mol^{-1}) Ignore just 'g' do not award 72.9 (g mol^{-1}) if rounded from 72.963 Correct answer with some working scores (4) Correct answer with no working scores zero Ignore premature rounding if final answer correct otherwise allow rounding to at least 3SF Ignore SF except 1 SF in final answer	

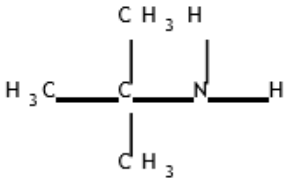
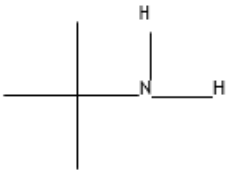
Q	Answer	Additional guidance	Mark
(b)(i)	• hydrogen chloride / HCl	Allow hydrochloric acid / HCl(aq)	1

Q	Answer	Additional guidance	Mark
(b)(ii)	• N-substituted amide / -CONHR	Accept amide / acid amide / -$CONH_2$ / -CONH- If name and formula are given, both must be correct	1

Q	Answer	Additional guidance	Mark
(b)(iii)	• conversion of percentages by mass into moles (1) • evaluation of moles **and** division by the smallest value to give a ratio (1) • conversion of ratio into an empirical formula (1)	Example of calculation C: % 62.6; mol 62.6/12 (=5.2167); Ratio 6.00 H: % 11.3; mol 11.3/1 (=11.3); Ratio 13.01 N: % 12.2; mol 12.2/14 (= 0.8714); Ratio 1.00 O: % 13.9; mol 13.9/16 =0.86875; Ratio 1.00 $C_6H_{13}NO$ Correct answer with no working scores (1) Ignore SF except 1 SF in mol calculation	3

Q	Answer	Additional Guidance	Mark
(c)	This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. **Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points** 6 – 4 5-4 – 3 3-2 – 2 1 – 1 0 – 0 The following table shows how the marks should be awarded for structure and lines of reasoning **Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout** – Number of marks awarded for structure of answer and sustained lines of reasoning: 2 **Answer is partially structured with some linkages and lines of reasoning** – 1 **Answer has no linkages between points and is unstructured** – 0	Guidance on how the mark scheme should be applied. The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general, it would be expected that 5 or 6 indicative points would get **2** reasoning marks, and 3 or 4 indicative points would get **1** mark for reasoning, and 0, 1 or 2 indicative points would score **0** marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). **Comment:** Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.	

Q	Answer	Additional guidance	Mark
(c) cont	Indicative points • **IP1** three peaks indicates three proton environments • **IP2** no splitting shows no proton environment is adjacent to another • **IP3** chemical shift = 7 (ppm) indicates N—**H** proton • **IP4** nine protons in one environment and no coupling indicates $(CH_3)_3C$— • **IP5** chemical shift = 2 (ppm) indicates C**H**$_3$C=O protons • **IP6** structure is 	Marks may be awarded for **IP**s annotated on the NMR or on the structure Allow three types of proton / hydrogen Allow 'peaks have one split' Accept $CH_3C=O$ indicated by amide responsible for the peak at 2 (ppm) Allow $CH_3C=O$ indicated by use of ethanoyl chloride Allow displayed, structural or skeletal formulae or any combination of these e.g. 	6

Q	Answer	Additional guidance	Mark
(d)		Allow displayed, structural or skeletal formulae or any combination of these e.g.  Allow TE on the amide in 19(c)providing **X** is shown as an amine	1
		(Total for Question = 17 marks)	

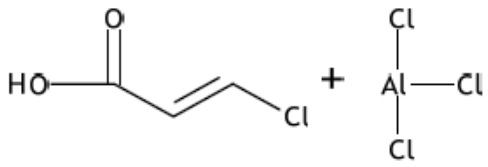
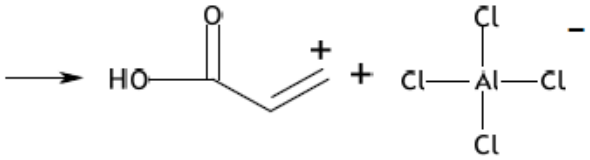
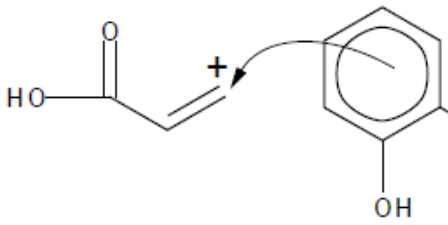
Q4.

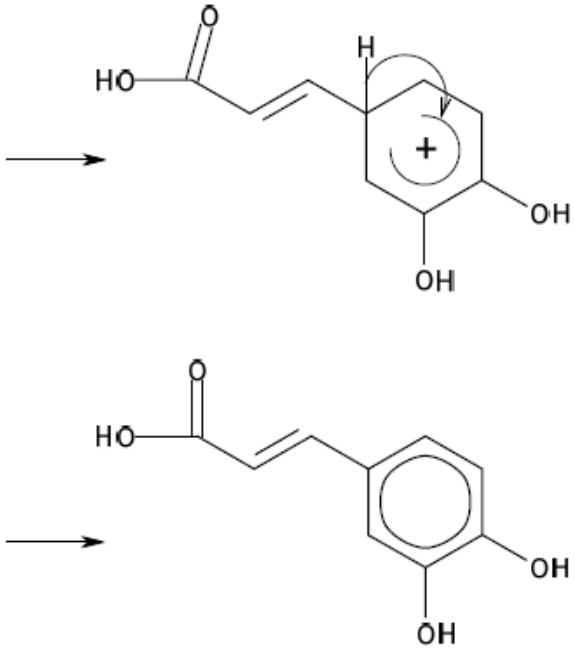
Question number	Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points • (π) electron system (in the right-hand ring) is delocalised (1) M2 and M3 scored from any **two** of • the delocalisation involves the lone-pair(s) in the nitrogen (atom(s)) and the π electrons of the double bonds (1) • (the right-hand ring) will undergo substitution reactions rather than addition reactions (1) • caffeine has stabilisation / delocalisation energy (1) • all the C—N bonds (in the 5-membered ring) will be the same (length)(1)	Allow aromatic ring Ignore just 'form aπ bond' Do not award just it is a benzene ring Allow just 'the delocalisation involves the lone-pair(s) in the nitrogen (atom(s)) Allow electrophilic substitution (rather than addition) Ignore electrophilic reaction Allow caffeine / (delocalised) ring is more stable Allow all the bonds will be the same length Ignore C=C bonds will be the same length	(3)

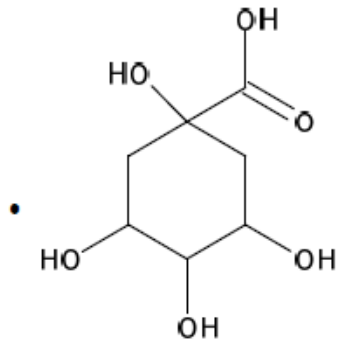
Question number	Answer	Additional guidance	Mark
(a)(ii)	An explanation that makes reference to the following points • Description of basicity (1) • Effect of delocalisation(1)	 Either lone pair donation Or proton acceptor Nitrogen lone pair incorporated in delocalised system / overlaps with the π (electron) ring **and** reduces electron density / lone pair availability Do not award overlap with the benzene ring Ignore references to the amide even if incorrect. If no other mark is scored the positive inductive effect of alkyl groups increases availability of the lone pair in a primary amine scores (1)	(2)

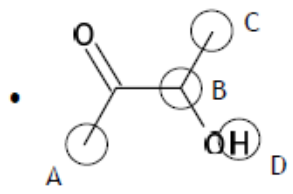
Question number	Answer	Additional guidance	Mark
(b)(i)	• determination of M_r (from molecular formula) (1) • calculation of amount of caffeine (1) • calculation of concentration of caffeine (1) • final answer to 1 or 2 SF (1)	Example of calculation $(C_8H_{10}N_4O_2)$ M_r = 194 $\frac{85}{1000 \times 194}$ (= 4.3814×10^{-4}/ 0.00043814) (mol) $= \frac{1000 \times 85}{200 \times 1000 \times 194} / \frac{1000 \times 0.00043814}{200}$ = 2.1907×10^{-3}/ 0.0021907 (mol dm^{-3}) = 2×10^{-3} /2.2×10^{-3} / 0.002 /0.0022(mol dm^{-3}) Do not award > 2 SF TE at each stage correct answer with no working scores (1)	(4)

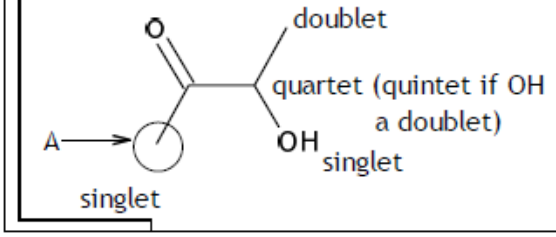
Question number	Answer	Additional guidance	Mark
(b)(ii)	• calculation of number of half-lives (1) • applies half-lives to three hours (1)	Example of calculation $\frac{20}{160} = \frac{1}{8} = \left(\frac{1}{2}\right)^n$ n = 3 or 160 → 80 → 40 → 20 (3 half lives) time = 3 x 3 = 9 hours TE on number of half lives calculated correct answer with some working scores (2)	(2)

Question number	Answer	Additional guidance	Mark
(c)(i)	A mechanism showing the following • structure of 3-chloropropenoic acid (1) • structure of the electrophile **and** balanced equation involving $AlCl_3$ and $AlCl_4^-$ (1) • curly arrow from on or within the circle to the positively charged carbon (1) **Allow any electrophile for M3, M4 and M5**	M1 and M2 are for the electrophile formation M3, M4 and M5 are for the electrophilic substitution Example of mechanism  Allow Br or I for Cl and Fe for Al Penalise errors in structure of 3-chloropropenoic acid / electrophile in M1 or M2 only   Allow curly arrow from anywhere in the hexagon Allow dotted horseshoe	(5)

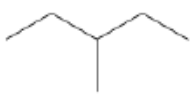
Question number	Answer	Additional guidance	Mark
(c)(i) cont	• intermediate structure including charge with horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon **and** with some part of the positive charge within the horseshoe (1) • curly arrow from C—H bond to anywhere in the benzene ring reforming delocalised structure with phenol groups in the 3 and 4 positions (1)	 penalise incorrect position / omission of the phenol groups at final marking point. Ignore omission of H^+ in final step correct Kekulé structures score full marks Ignore structure of substituents apart from the position of the OH groups in final structure	

Question number	Answer	Additional guidance	Mark
(c)(ii)	•  	or displayed structure Allow COOH and CO_2H Ignore all connectivity errors to 'OH' Only penalise O–H–C	(1)

Question number	Answer	Additional guidance	Mark
(d)(i)		Allow any labelling sequence Do not award any other labelling	(1)

Question number	Answer	Additional guidance	Mark
(d)(ii)	<table><tr><th>Proton environment (labelled as in (i))</th><th>Splitting pattern</th></tr><tr><td>A</td><td>singlet</td></tr><tr><td>B</td><td>quartet</td></tr><tr><td>C</td><td>doublet</td></tr><tr><td>D</td><td>singlet</td></tr></table> OR 	all four correct (2) three correct (1) Allow non-standard terms such as 'two splits' or just '2' for doublet If D (OH proton) is given as a doublet, allow B as a quartet **or** as a quintet Ignore carbonyl carbon labelled as a proton environment	(2)

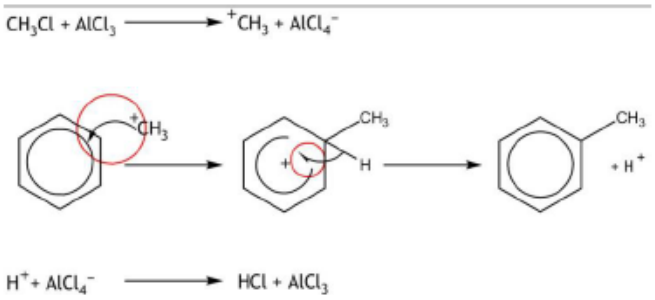
Q5.

Question number	Answer	Mark
	The only correct answer is B  ***A*** *is incorrect because this isomer gives 3 peaks* ***C*** *is incorrect because this isomer gives 5 peaks* ***D*** *is incorrect because this isomer gives 2 peaks*	(1)

Q6.

Question number	Answer	Mark
	A C_6H_5–NH_2 < H–NH_2 < CH_3–NH_2	1

Q7.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • circle around arrow from $^+CH_3$ to ring (wrong direction) (1) • circle around arrow from bond attached to H, to partial ring (single-headed arrow) (1)		(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • arrow should move from ring / arrow is going the wrong way **and** ring is electron-rich / as ring cannot accept electrons / as $^+CH_3$ does not have a lone pair (of electrons) / as $^+CH_3$ needs to gain electrons / as $^+CH_3$ is an electrophile (1) • arrow (from C-H bond) should be double-headed **and** as both electrons in the bond pair move (to complete the ring) / as moving a single electron would not complete the ring / as moving a single electrons would form (free) radicals (1)	If no other credit awarded, then 1 mark can be given for both corrections correctly identified	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	An answer that makes reference to one of the following points: • to prevent further substitutions (of nitro groups)	Allow methylbenzene is (more) reactive (than benzene) **and** because a methyl group is electron releasing Allow ring in methylbenzene is (more) electron-rich (than benzene) Allow forms dinitrobenzene / trinitrobenzene Ignore further reactions / forms other products	(1)

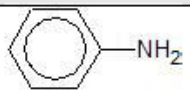
Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	An answer that makes reference to the following point: • oxidation	Allow oxidation and reduction / oxidation and redox Ignore references to redox	(1)

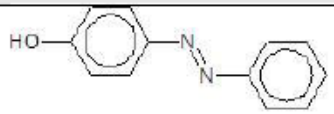
Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	An answer that makes reference to the following point: • Sn **and** (concentrated) HCl	Accept correct names Allow Zn as alternative to Sn Ignore references to concentration or state of HCl Ignore any references to heat / temperature Ignore addition of NaOH after reaction with Sn and HCl	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to three of the following points: • (carbonyl) carbon is electron-deficient / has a partial positive charge • nitrogen (on NH_2 group) has a lone pair (of electrons) • which move to (carbonyl) carbon (to form bond) / which form a bond with the (carbonyl) carbon • Cl is a good leaving group / bond to Cl breaks / C-Cl bond pair moves to Cl	Allow M1, M2 and M3 on a clearly annotated diagram Ignore references to delocalisation Ignore references to nucleophilic substitution / nucleophilic additionelimination	(3)

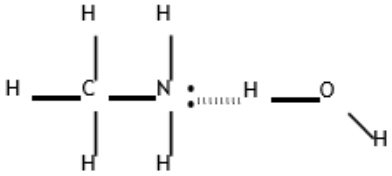
Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	• calculation of moles of 2-ethanoylaminobenzoic acid (1) • calculation of moles of benzene required, taking into account the overall percentage yield (1) • calculation of mass of benzene (1) • calculation of volume of benzene to 1/2/3 SF (1)	<u>Example of calculation</u> $5.92 \div 179 = 0.033073$ (mol) / 3.3073×10^{-2} $0.033073 \times (100 \div 28.2) = 0.11728$ (mol) $0.11728 \times 78 = 9.1477$ (g) $9.1477 \div 0.879 = 10.407$ $= 10.4$ / 10 cm^3 Ignore absence of units but do not award incorrect units. Marks 2 – 4 can be in any order Allow TE throughout Answer of 10 cm^3 with no working scores M4 only Correct answer with some working scores 4	(4)

Q8.

Question number	Answer	Mark
(a)	A HNO_2 	1

Question number	Answer	Mark
(b)	 B	1

Q9.

Q	Answer	Mark
	The only correct answer is B  ***A*** *is not correct because the N ---H—O bond angle should be 180°* ***C*** *is not correct because hydrogen atoms bonded to carbon atoms cannot form hydrogen bonds* ***D*** *is not correct because hydrogen atoms bonded to carbon atoms cannot form hydrogen bonds*	1

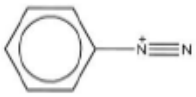
Q10.

Question number	Answer	Mark
	The only correct answer is D (a polyamide but not a polypeptide) ***A*** *is incorrect because polypeptides are formed from amino acids* ***B*** *is incorrect because it is a polyamide* ***C*** *is incorrect because it cannot be a polypeptide*	(1)

Q11.

Question number	Answer	Mark
	The only correct answer is C (2-methylbutanamide) ***A*** *is incorrect because the amide carbon is part of the main carbon chain* ***B*** *is incorrect because the amide carbon is part of the main carbon chain* ***D*** *is incorrect because the carbon chain is numbered from the amide end*	**(1)**

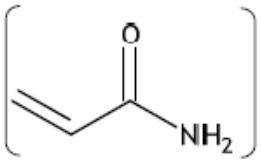
Q12.

Question Number	Correct Answer	Mark
	The only correct answer is D  *A is incorrect because it is the phenylammonium ion* *B is incorrect because the bonding and charge is incorrect on the right hand nitrogen* *C is incorrect because the structure is an amine with a positive charge*	**(1)**

Q13.

Question number	Answer	Mark
	The only correct answer is C ($C_{11}H_{14}O$) ***A*** *is incorrect because there are 6 carbon atoms in the ring, 3 in the side-chain on the left and 2 in the side chain on the right* ***B*** *is incorrect because there are 6 carbon atoms in the ring, 3 in the side-chain on the left and 2 in the side chain on the right* ***D*** *is incorrect because there are no hydrogen atoms on the carbon atoms in the ring where there are side-chains*	**(1)**

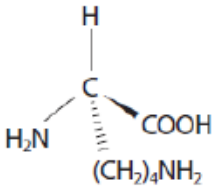
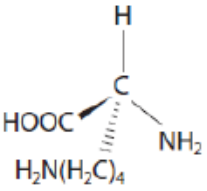
Q14.

Question number	Answer	Mark
	The only correct answer is A 	(1)
	B *is incorrect because this monomer has four carbon atoms not three and would give a polymer with a methyl group on a different carbon to the amide group*	
	C *is incorrect because this monomer has four carbon atoms not three and would give a polymer with a methyl group branched chain*	
	D *is incorrect because this monomer has five carbon atoms not three and would give a polymer with two methyl group branched chains*	

Q15.

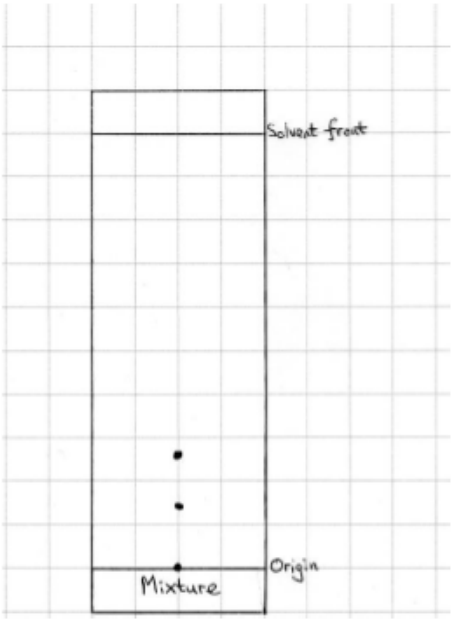
Question number	Answer	Additional guidance	Mark
(a)	A suitable equation such as: • $NH_2CH_2COOH + NaOH \rightarrow NH_2CH_2COO^{(-)}Na^{(+)} + H_2O$	Allow zwitterion ionic equation displayed formulae Ignore state symbols even if incorrect Do not award O-Na	1

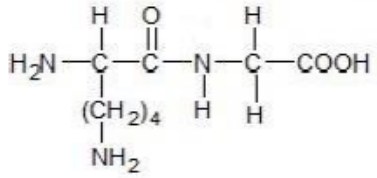
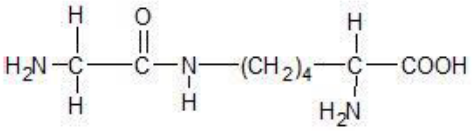
Question number	Answer		Additional guidance	Marks
(b)	• number of moles of lysine **and** number of moles of HCl	(1)	Example of calculation: n(1.825 ÷ 146=) 0.0125 (mol) n(0.0125 × 2=) 0.025 (mol)	2
	• volume of HCl in cm^3	(1)	V = (0.025 ÷ 0.100) × 1000 = 250 cm^3 Allow answer in dm^3 Allow 1 mark for 125 cm^3	

Question number	Answer	Additional guidance	Marks
(c)(i)	 (1)  (1)	Structures must be 3-dimensional Allow any orientation	2

Question number	Answer	Additional guidance	Marks
(c)(ii)	A description which includes: • the plane of plane-polarised (monochromatic) light (1) • will be rotated equally but in opposite directions by the two enantiomers/left by one (laevo-rotatory) enantiomer and to the right by the other (dextro-rotatory) enantiomer. (1)	Allow omission of one plane Allow use of d and l/(+) and (–) Do not award use of D and L	2

Question number	Answer	Additional guidance	Marks
(c)(iii)	• glycine does not have a chiral carbon/centre or asymmetric carbon or is superimposable on its mirror image		1

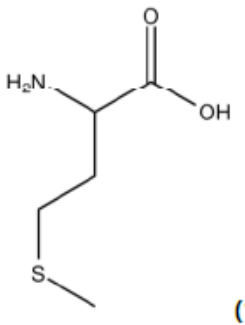
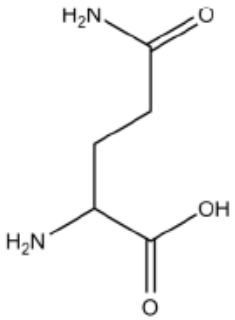
Question number	Answer	Additional guidance	Marks
(d)	A suitable diagram such as: 	Allow spots of any reasonable size and anywhere within the range for lysine 0.1-0.2 and for glycine 0.2-0.3	1

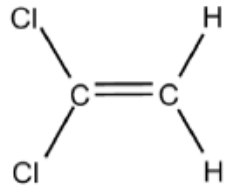
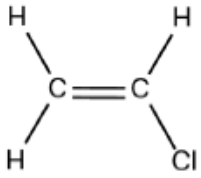
Question number	Answer	Additional guidance	Marks
(e)	A diagram such as: • 	Allow: 	1

Q16.

Question number	Answer	Mark
	The only correct answer is C (phenylamine, ammonia, butylamine) **A** *is incorrect because butylamine has the highest pH and phenylamine the lowest* **B** *is incorrect because phenylamine has the lowest pH* **D** *is incorrect because phenylamine has a lower pH than ammonia*	(1)

Q17.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	 (1)  (1)	Do not award acyl chlorides	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	 (1)  (1)	Allow displayed / structural / skeletal formula or any correct hybrid of the 3 types of structure e.g. CCl_2CH_2 (1) and CH_2CHCl (1)	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• calculation of molar mass of repeat unit (1) • calculation of number of repeat units (1)	Example of calculation (12 × 12) + 14 = 158 (g mol^{-1}) 300 000 ÷ 158 = 1898.73 = 1900 (units) Allow 1898 / 1899 i.e allow the value to be rounded up or rounded down Ignore SF Final answer must be whole number Allow TE for incorrect molar mass	(2)

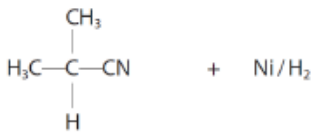
Q18.

Question Number	Correct Answer	Mark
(a)	**The only correct answer is B** (62.5 %) *A is incorrect because the two carbonyl carbon atoms have not been included* *C is incorrect because the hydrogen atoms have not been included* *D is incorrect because two additional carbon atoms have been included*	(1)

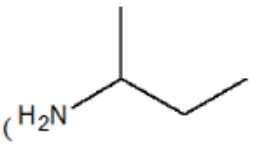
Question Number	Correct Answer	Mark
(b)	**The only correct answer is B** (3) ***A*** *is incorrect because the carbons in the benzene ring are not all in the same environment* ***C*** *is incorrect because there are only 2 different carbon environments in the benzene ring* ***D*** *is incorrect because there are only 2 different carbon environments in the benzene ring*	(1)

Question Number	Correct Answer	Mark
(c)	**The only correct answer is A** (a single type of monomer by an addition reaction) ***B*** *is incorrect because the polymer is not formed by a condensation reaction* ***C*** *is incorrect because the polymer is not formed by two different types of monomer* ***D*** *is incorrect because the polymer is not formed by two different types of monomer or a condensation reaction*	(1)

Q19.

Question number	Answer	Mark
	 A	1

Q20.

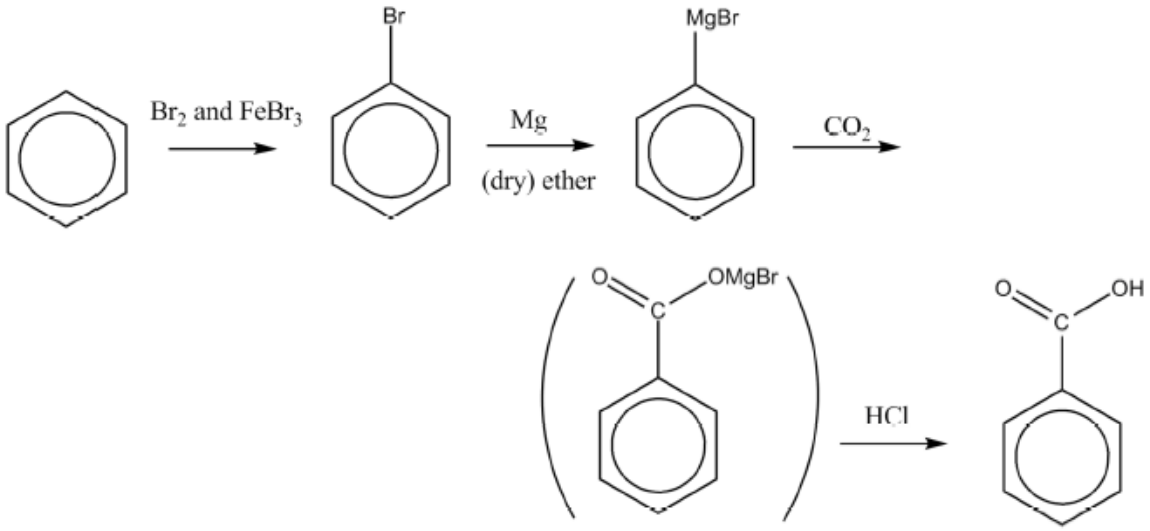
Question number	Answer	Mark
	The only correct answer is B () ***A*** *is incorrect because this amine could be prepared by the reduction of butanenitrile* ***C*** *is incorrect because this amine could be prepared by the reduction of 2-methylpropanenitrile* ***D*** *is incorrect because this amine could be prepared by the reduction of 2,2-dimethylpropanenitrile*	**1**

Q21.

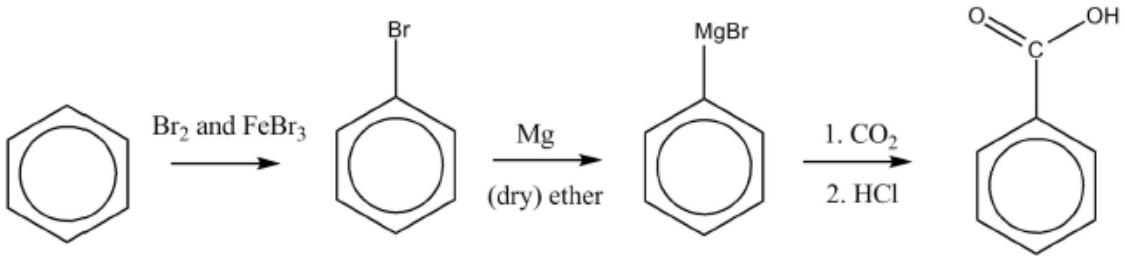
Question number	Answer	Mark
	C $CH_3COCl + NH_3 \rightarrow CH_3CONH_2 + HCl$	1

Q22.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • reaction of benzene with Br_2 and $FeBr_3$ / $AlBr_3$ **(1)** • reaction of bromobenzene with Mg **(1)** • in (dry) ether **(1)** • structure of Grignard reagent **(1)** • reaction of Grignard reagent with CO_2 / **(1)** • (hydrolysis of acid salt) with dilute HCl **(1)** Alternative route for M5 and M6 • reaction of Grignard reagent with HCHO **(1)** • (hydrolysis of acid salt) with dilute HCl **and** oxidation (of primary alcohol) with acidified $Cr_2O_7^{2-}$ **(1)**	See below for reaction scheme Ignore references to heating / refluxing throughout Allow Fe & Br_2 Allow other halogens and halides Allow aluminium halide M5 and M6 with CO_2 can be shown in the same part of the process providing it it's clear that each step is separate e.g. by labelling (see example below) Allow any dilute acid / H^+ Ignore structure of salt Ignore H_2O	**(6)**

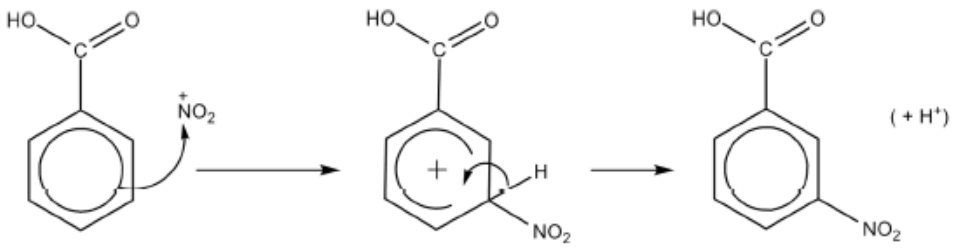


Allow CO_2 and HCl as parts 1 and 2 of the final step if clearly labelled e.g.



Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An answer that makes reference to the following points: • equation to show formation of electrophile **(1)**	$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$ Or $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$ Or $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ and $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ Do not award $H_3SO_5^-$ in M1 but allow as potential TE in M5	**(5)**
	• curly arrow from anywhere on the central ring to positive **nitrogen** **(1)**	Allow curly arrow from anywhere **within** the hexagon	
	• structure of intermediate **(1)**	Horseshoe facing the tetrahedral carbon and covering at least three carbon atoms. Some part of the positive charge in the horseshoe Do not award dotted lines unless clearly part of a 3D structure	
	• curly arrow from C-H bond to reform the ring **(1)**	Do not award M4 if substitution position is incorrect	
	• equation showing regeneration of catalyst **(1)**	$HSO_4^- + H^+ \rightarrow H_2SO_4$ Allow M5 as part of mechanism, with curly arrow from oxygen of HSO_4^- to H on benzene ring	

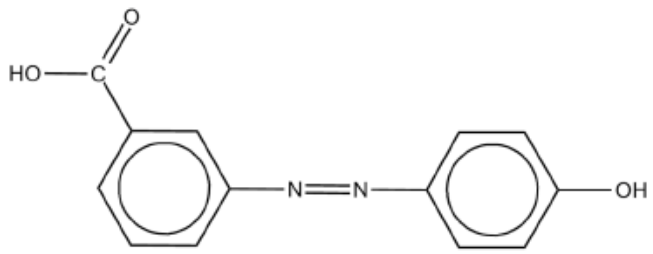
Example of mechanism for bi



Ignore postion of '+' in NO_2^+
No TE from incorrect species from equation in M1 to M2
Use of benzene can score M1, M2, M3 and M5

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• Sn and (concentrated) HCl / tin and (concentrated) hydrochloric acid	Allow Fe for Sn Do not award other acids e.g. sulfuric acid Do not award $LiAlH_4$ Do not award Sn is a catalyst Do not award dilute HCl Do not award 'followed by NaOH' Ignore heating / reflux / stated temperatures	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	An explanation that makes reference to the following points: • any temperature between 0°C and 10°C , inclusive **(1)** • to prevent formation of by-products / phenol (compounds) **(1)**	Mark independently Allow just 'less than 10°C' / 'below 5°C' Allow to prevent decomposition of HNO_2 / to prevent decomposition of diazonium ion/ diazonium ion is unstable / to prevent weak C-N bond breaking / prevent formation of (stable) nitrogen Allow reaction is too slow at temperatures below 0°C / low temperatures Do not award decomposition of $NaNO_2$ / nitro group	**(2)**

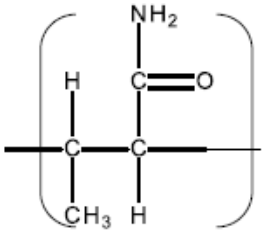
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)		Ignore additional products Ignore connectivity of -OH group Do not award if OH or COOH are at incorrect positions on ring Do not award carboxylate ion Do not award $-N_2-$ in between two rings Do not award N≡N	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• calculation of molar mass of $Pb(C_6H_5COO)_2$ **(1)** • calculation of amount of $Pb(C_6H_5COO)_2$ **(1)** • deduction of amount of $Ca(C_6H_5COO)_2.xH_2O$ **(1)** • calculation of M_r of $Ca(C_6H_5COO)_2.xH_2O$ **(1)** • calculation of mass of water in M_r **(1)** • calculation of amount of water and hence x **(1)** **Alternative route for M4-M6** • calculation of mass of $Ca(C_6H_5COO)_2$ **(1)** • calculation of mass of water in hydrated sample **(1)** • calculation of amount of water and hence x **(1)**	Example of calculation 449.2 can be subsumed within M2 $3.89 / 449.2 = 8.65984 \times 10^{-3}$ (mol) 1:1 so 8.65984×10^{-3} (mol) M3 can be subsumed in M4 $2.60 / 8.65984 \times 10^{-3} = 300.24$ 300.24 – (40.1 + (14x12) + (1x10) + (4x16) = 18.14 18.14 ÷18 = 1, so x = 1 Allow TE throughout Correct value for x with no working scores M6 only $8.65984 \times 10^{-3} \times 282.1 = 2.44$ g 2.60 – 2.44 = 0.16 g 0.16 ÷18 = 0.000889, so x = 1 Ignore SF except 1 SF for M1-M5	**(6)**

Q23.

Question number	Answer	Mark
	The only correct answer is A ($Cr_2O_7^{2-} + 2C \rightarrow Cr_2O_3 + CO_3^{2-} + CO$) ***B*** *is incorrect because chromium has oxidation number +6 in the reactant and product and no other atom is changing oxidation number* ***C*** *is incorrect because chromium has oxidation number +6 in the reactant and product and no other atom is changing oxidation number* ***D*** *is incorrect because chromium has oxidation number +6 in the reactant and product and no other atom is changing oxidation number*	**(1)**

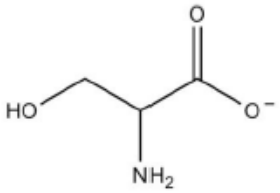
Q24.

Question number	Answer	Mark
	The only correct answer is A 	(1)
	B *is incorrect because the methyl group cannot form part of the polymer chain*	
	C *is incorrect because the peptide link cannot form from an amide group*	
	D *is incorrect because the methyl group cannot form part of the polymer chain and the peptide link cannot form from an amide group*	

Q25.

Question number	Answer	Mark
	The only correct answer is B (4)	1
	A *is incorrect because the repeat unit of the polymer is formed from four different amino acids*	
	C *is incorrect because the repeat unit of the polymer is formed from four different amino acids*	
	D *is incorrect because the repeat unit of the polymer is formed from four different amino acids*	

Q26.

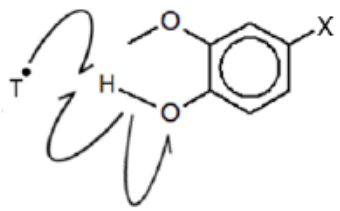
Question Number	Correct Answer	Mark
(a)	**The only correct answer is D**  *A is incorrect because this ion would form in an acidic solution* *B is incorrect because this is the zwitterion* *C is incorrect because the OH group would not lose a proton*	(1)

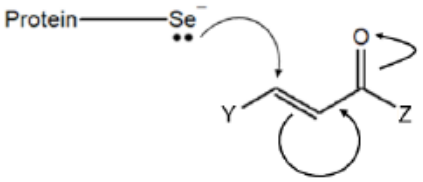
Question Number	Correct Answer	Mark
(b)	**The only correct answer is B** (ionic bonds) *A is incorrect because ionic bonds are far stronger than any hydrogen bonds* *C is incorrect because ionic bonds are far stronger than any London forces* *D is incorrect because the formation of a peptide bond forms a dipeptide*	(1)

Q27.

Question number	Answer	Mark
	The only correct answer is A (N_2O_5) ***B*** *is incorrect because Br has oxidation number +5 and Mn has oxidation number +7* ***C*** *is incorrect because Br has oxidation number +5 and Fe has oxidation number +6* ***D*** *is incorrect because Br has oxidation number +5 and S has oxidation number +4*	(1)

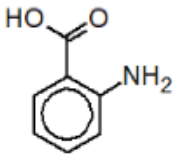
Q28.

Question Number	Answer	Additional guidance	Mark
(a)	A completed mechanism showing: • curly half-arrows to show homolytic fission of O–H bond	Example of completed mechanism:  Accept curly half-arrows originating from opposite sides of the O–H bond Left-hand curly half-arrow must terminate between T• and H Right hand curly half-arrow must terminate on or near to O atom of H–O	1

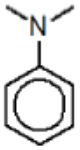
Question Number	Answer	Additional guidance	Mark
(b)	A completed mechanism showing: • curly arrow from lone pair on Se^- to correct C of C=C (1) • curly arrow from C=C bond to C–C bond **and** curly arrow from C=O bond to O (1)	Example of completed mechanism:  Penalise curly half-arrows once only Do not award curly arrow from negative charge on Se^- Ignore (δ+)C=C(δ–) dipole Do not award (δ-)C=C(δ+) dipole Do not award full charge on either carbon of C=C bond Do not award incorrect (δ-)C=O(δ+) dipole	2

Question Number	Answer	Additional guidance	Mark
(c)	A completed table showing: • two or three correct answers (1) • four correct answers (2)	Example of completed table: [Au(Curc)$_2$]$^+$ / [Al(Curc)(C_2H_5OH)$_2$(NO_3)$_2$] Coordination number: 4 / <u>6</u> O–M–O bond angle: 90° / <u>90°</u> Ignore 180° Shape: <u>square planar</u> / octahedral Charge on metal ion: <u>+3</u> / +3	2

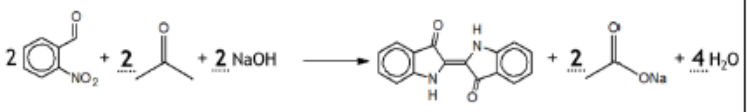
Question Number	Answer	Additional guidance	Mark
(d)(i)	• $K_2Cr_2O_7$ and H_2SO_4 (1) • heat/reflux (1)	**If name and formula given, both must be correct to score M1** Accept names (eg sodium dichromate((VI)) and sulfuric acid) Allow $Cr_2O_7^{2-}$ and H^+ / acidified dichromate Ignore concentration of acid Do not award $KMnO_4$ for $K_2Cr_2O_7$ Do not award HCl for H_2SO_4 **M2 dependent on some mention of dichromate (or manganate) oxidising agent** Ignore distillation	2

Question Number	Answer	Additional guidance	Mark
(d)(ii)	• correct structure for 2-aminobenzoic acid	Example of correct structure:  Accept hydrochloride salt ($-NH_3Cl$) Allow protonated amine group ($-NH_3^+$) Allow any correct combination of skeletal, structural or displayed formulae Allow Kekulé benzene Ignore connectivity Ignore name, even if incorrect	1

Question Number	Answer	Additional guidance	Mark
(d)(iii)	• $NaNO_2$/sodium nitrite/sodium nitrate(III) **and** HCl/hydrochloric acid	Allow HNO_2/nitrous acid Allow H^+ **and** NO_2^- Ignore conditions, including concentration of HCl Ignore H_2O Do not award $NaNO_3$/sodium nitrate	1

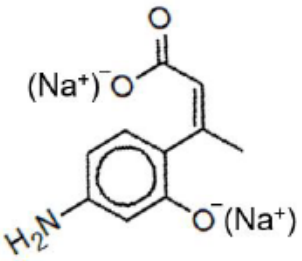
Question Number	Answer	Additional guidance	Mark
(d)(iv)	• correct structure for *N*,*N*-dimethylphenylamine	Example of correct structure:  Allow any correct combination of skeletal, structural or displayed formulae Allow Kekulé benzene Ignore quaternary salt ($-N(CH_3)_3^+$) Ignore name, even if incorrect	1

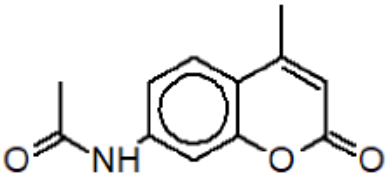
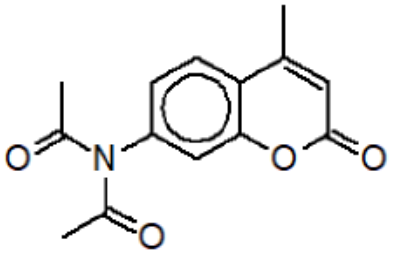
Question Number	Answer	Additional guidance	Mark
(d)(v)	An explanation including: • effect of temperature higher than 5°C (1) • effect of temperature lower than 5°C (1)	(diazonium/it) decomposes / reacts with water / forms a phenol / undergoes nucleophilic substitution (above 5°C) Ignore byproducts form / side reactions occur / yield too low (above 5°C) (rate of reaction) too slow (below 5°C) Allow just slows down (below 5°C) Ignore insufficient energy for reaction to occur (below 5°C) Ignore any reference to activation energy/collision frequency Ignore freezes (at 0°C and below)	2

Question Number	Answer	Additional guidance	Mark
(e)(i)	A completed equation showing: • correct balancing of propanone and sodium ethanoate (1) • correct balancing of sodium hydroxide and water (1)	Example of equation:  **M2 dependent on M1**	**2**

Question Number	Answer	Additional guidance	Mark
(e)(ii)	**M1: molar masses** • M(2-nitrobenzaldehyde) **and** M(indigotin) (1) Then, for M2 and M3, either:	Correct answer with no working scores (3) Example of calculation: M(2-nitrobenzaldehyde) = 7 × 12.0 + 5 × 1.0 + 1 × 14.0 + 3 × 16.0 = 151(.0 g mol^{-1}) M(indigotin) = 16 × 12.0 + 10 × 1.0 + 2 × 14.0 + 2 × 16.0 = 262(.0 g mol^{-1}) Allow truncation of mass/moles throughout, eg 0.03816 for 0.038168 Ignore SF except 1 SF in M2 and M3	**3**

	Method 1 (M2 and M3) • moles indigotin in 10.0 g **and** indigotin:2-nitrobenzaldehyde mol ratio (1) • moles 2-nitrobenzaldehyde required **and** mass 2-nitrobenzaldehyde required (1) OR **Method 2 (M2 and M3)** • mass indigotin if 100% yield **and** moles indigotin if 100% yield (1) • indigotin:2-nitrobenzaldehyde mol ratio **and** mass 2-nitrobenzaldehyde (1)	moles indigotin in 10.0 g = $\frac{10.0}{262}$ = 0.038168 TE on *M*(indigotin) moles 2-nitrobenzaldehyde = 2 × 0.038168 (= 0.076336) TE on moles indigotin moles 2-nitrobenzaldehyde required = $\frac{100}{85}$ × 0.076336 = 0.089807 mass 2-nitrobenzaldehyde required = 0.089807 × 151 = 13.561 = 14 (g) TE on moles 2-nitrobenzaldehyde TE on *M*(2-nitrobenzaldehyde) mass indigotin if 100% yield = $\frac{100}{85}$ × 10.0 = 11.765 (g) moles indigotin if 100% yield = $\frac{11.765}{262}$ = 0.044903 TE on *M*(indigotin) moles 2-nitrobenzaldehyde = 2 × 0.044903 (= 0.089807) TE on moles indigotin mass 2-nitrobenzaldehyde = 0.089807 × 151 = 13.561 = 14 (g) TE on moles 2-nitrobenzaldehyde TE on *M*(2-nitrobenzaldehyde)	

Question Number	Answer	Additional guidance	Mark
(f)(i)	A drawing showing: • hydrolysed ester linkage **and** correct carbon frame and amine group (1) • deprotonated carboxylic acid **and** phenol groups (1)	Example of drawing:  Allow –ONa Do not award –O–Na Allow *E* isomer Allow Kekulé benzene Allow any correct combination of skeletal, structural or displayed formulae	2

Question Number	Answer	Additional guidance	Mark
(f)(ii)	A drawing showing: • correct condensation product	Example of drawing:  Allow Kekulé benzene Allow any correct combination of skeletal, structural or displayed formulae Allow diacylated product, ie  	1

Q29.

Question number	Answer	Mark
	The only correct answer is B($CH_3CH_2CH_2CH_2NH_3Cl$) ***A*** *is incorrect because substitution does not occur in these conditions* ***C*** *is incorrect because an amide does not form in this way* ***D*** *is incorrect because a carboxylic acid does not form in these conditions*	**(1)**

Q30.

Question number	Answer	Mark
	The only correct answer is C(butanenitrile; lithium tetrahydridoaluminate(III)) ***A*** *is incorrect because propanenitrile would give propylamine* ***B*** *is incorrect because propanenitrile would give propylamineand tin with HCl does not reduce nitriles* ***D*** *is incorrect because tin with HCl does not reduce nitriles*	**(1)**