PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 18: ORGANIC CHEMISTRY III

SCORE	PERCENTAGE
/585	%

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Q1.

Bromine reacts much faster with phenylamine than with benzene. This is because

☒ **A** N—H bonds are weaker than C—H bonds.

☒ **B** nitrogen is very electronegative.

☒ **C** the benzene ring has greater electron density in phenylamine than in benzene.

☒ **D** phenylamine reacts by addition whereas benzene reacts by substitution.

(Total for question = 1 mark)

Q2. Phenylamine, $C_6H_5NH_2$, and benzene react with bromine in a similar way, but phenylamine reacts much faster. This increased rate of reaction is most likely due to the effect that the

☒ **A** electronegativity of the nitrogen has on the benzene ring.

☒ **B** electronegativity of the nitrogen has on the bromine molecule.

☒ **C** lone pair of electrons of the nitrogen has on the benzene ring.

☒ **D** lone pair of electrons of the nitrogen has on the bromine molecule.

(Total for Question = 1 mark)

Q3.

This question is about amines.

Phenylamine is an aromatic amine and butylamine is an aliphatic amine.

Phenylamine can be prepared from nitrobenzene.



Butylamine can be prepared from butanenitrile.

$$C_3H_7CN \rightarrow C_4H_9NH_2$$

Compare and contrast these two preparations of amines.

(3)

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(Total for question = 3 marks)

Q4.

This question is about amines.

(a) Amines can behave as bases.

What is meant by the term base?

(1)

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(b) Which of these compounds has the highest pH when dissolved in water to form solutions of the same concentration?

(1)

☒ **A** NH_3

☒ **B** CH_3NH_2

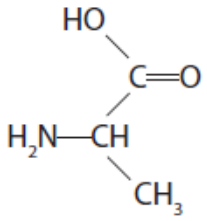
☒ **C** $C_6H_5NH_2$

☒ **D** NH_4Cl

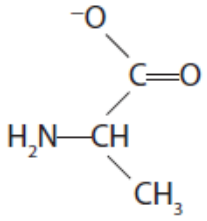
Q5.

In an aqueous solution with a pH of 12, the amino acid alanine exists mainly as

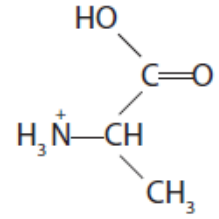
☐ **A**



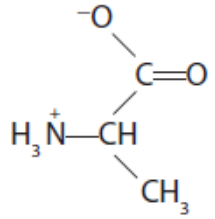
☐ **B**



☐ **C**



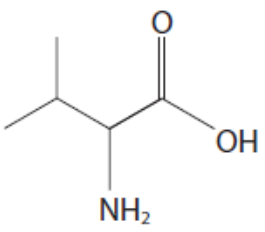
☐ **D**



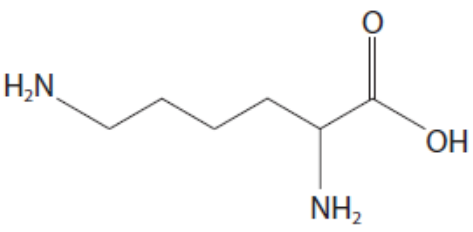
(Total for question = 1 mark)

Q6.

The structures of two amino acids are shown.



valine



lysine

Give the **skeletal** formula for

(i) valine in a solution at pH 10

(1)

(ii) lysine in a solution at pH 2

(1)

Q7.

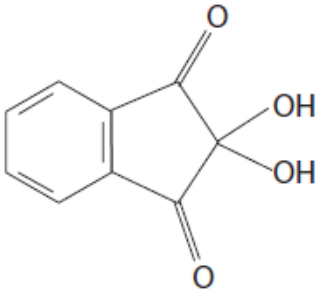
Read the passage below carefully and answer the question which follows.

The general formula of most naturally occurring amino acids can be written $RCH(NH_2)COOH$, though in some amino acids, such as proline, the nitrogen atom is part of a five-membered ring. Amino acids are water soluble, though the extent of their solubility varies. All but one of the naturally occurring amino acids show optical activity.

The formula of the R group for some naturally occurring amino acids is shown below.

Amino acid	Formula of R group
serine	$-CH_2OH$
lysine	$-(CH_2)_4NH_2$
phenylalanine	$-CH_2C_6H_5$
leucine	$-CH_2CH(CH_3)_2$
iso-leucine	$-CH(CH_3)CH_2CH_3$
alanine	$-CH_3$

Mixtures of amino acids can be separated by electrophoresis. This method depends on amino acids moving different distances through paper or gel when an electric field is applied. They can also be separated by chromatography. Ninhydrin, shown below, is the chemical which is used to locate the position of the amino acids on chromatograms.



Ninhydrin detects ammonia and primary and secondary amines. When it reacts with primary amines, a deep blue or purple colour is produced in a complex series of reactions. With proline, a yellow compound forms.

Ninhydrin is widely used to detect fingerprints. Sweat secretions from ridges on the finger contain dipeptides and proteins. These are left on porous surfaces such as paper, and react with ninhydrin.

When ninhydrin reacts with amino acids, carbon dioxide is released from the carboxylic acid group. Archaeologists have used this reaction to release the carbon from proteins in ancient bones, and, by comparing the proportions of carbon and nitrogen in the remains, they have obtained evidence for the diets of these animals.

(a) (i) At a pH of 5.68, serine exists as a zwitterion. Draw the formula of serine at this pH.

(1)

*(ii) At pH 5.68, serine and lysine can be separated by electrophoresis. By considering the structures of the amino acids at this pH, suggest why this separation occurs.

(2)

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*(b) Serine is very soluble in water, whilst phenylalanine is much less soluble. Explain the difference, disregarding any effect of zwitterion formation.

(2)

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(c) The naturally occurring amino acid which does not show optical activity is not shown in the table. Give the formula of the R group for this acid.

(1)

(d) The optical activity of equimolar solutions of naturally occurring samples of leucine and iso-leucine can be measured in an experiment using plane-polarized light.

(i) What measurement is made to show the optical activity of amino acids?

(1)

.....

(ii) By considering the structures of iso-leucine and leucine, explain why iso-leucine has more stereoisomers than leucine.

Amino acid	Formula of R group
leucine	$-CH_2CH(CH_3)_2$
iso-leucine	$-CH(CH_3)CH_2CH_3$

(1)

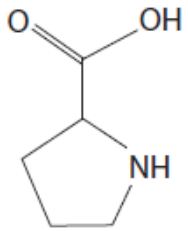
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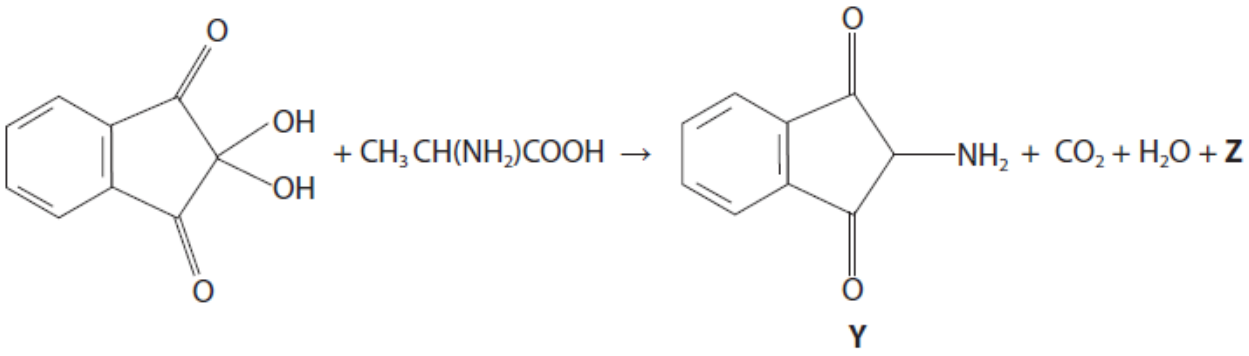
(e) The amino acid proline, shown below, does not contain a primary amine group, but it can still form peptide bonds.



Draw the structure of the dipeptide formed when the carboxylic acid group of alanine reacts with proline. Circle the peptide group on your drawing.

(2)

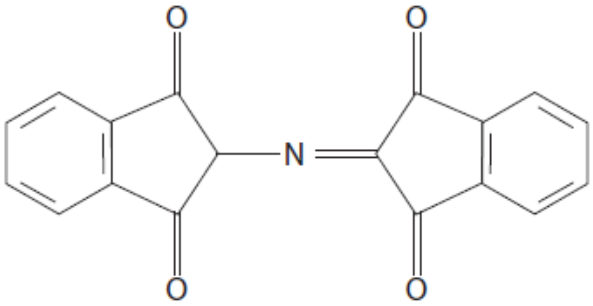
(f) The first steps of the reaction of ninhydrin with alanine can be summarised in the equation shown below.



(i) By balancing the equation, suggest the structural formula of the product **Z**.

(1)

(ii) In the final stage, **Y** reacts with another molecule of ninhydrin to form a dye, **Q**, shown below.



What is the molecular formula of **Q**?

(1)

(iii) On combustion, 1.000 g of **Q** produces 2.614 g carbon dioxide, 0.2673 g water and 0.04620 g nitrogen.

Use these data to calculate the percentage composition by mass of **Q**, and hence its empirical formula. Show whether your answer is consistent with the molecular formula of **Q**.

(4)

(iv) Evidence for the structure of **Q** is obtained from data in its mass spectrum, and the number of peaks in its low resolution nmr spectrum.

Suggest **one** piece of evidence from **each** type of spectroscopy which would support the structure shown in (ii). Give data where appropriate.

(2)

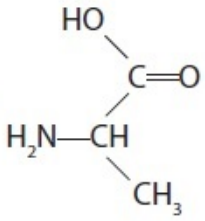
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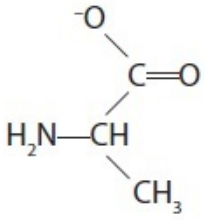
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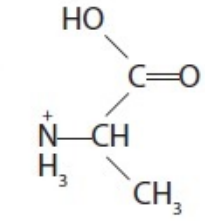
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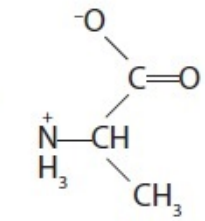
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Q8. Which of the following structures best represents the amino acid, alanine, in an aqueous solution with a pH of 12?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question = 1 mark)

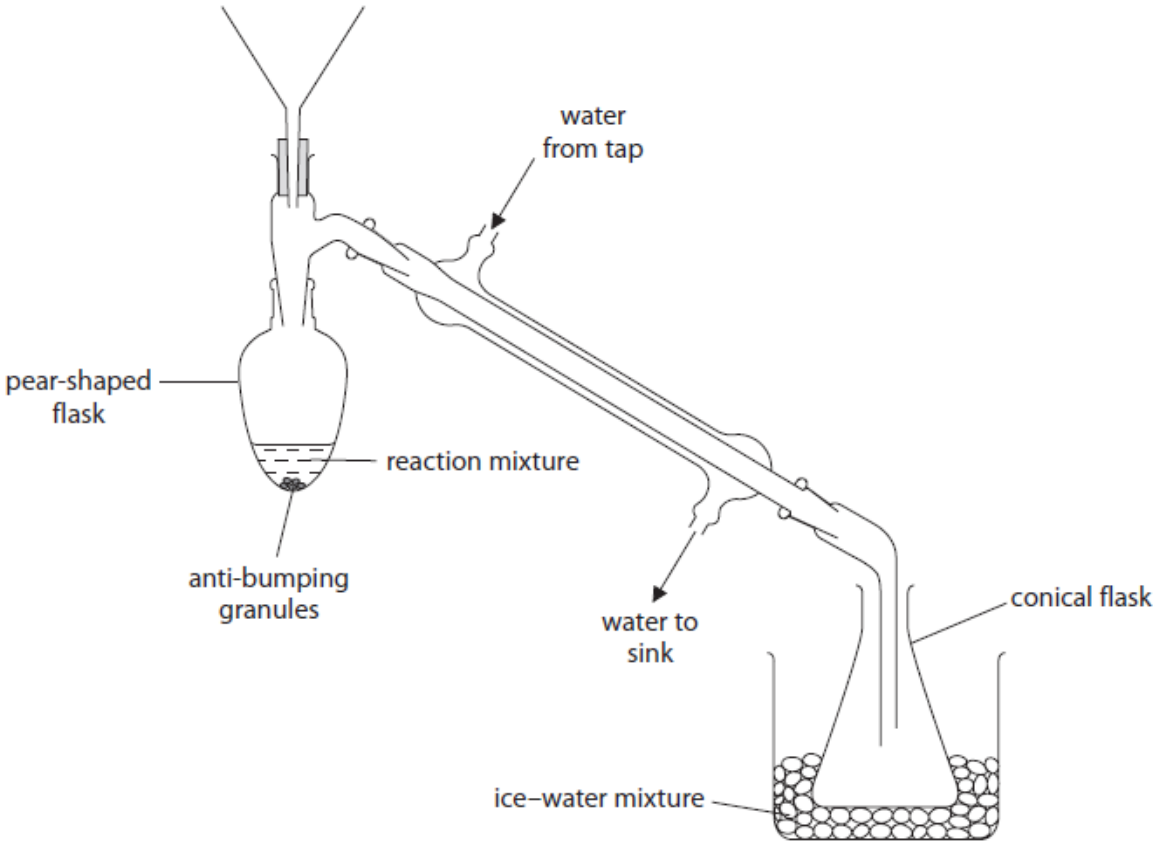
Q9.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

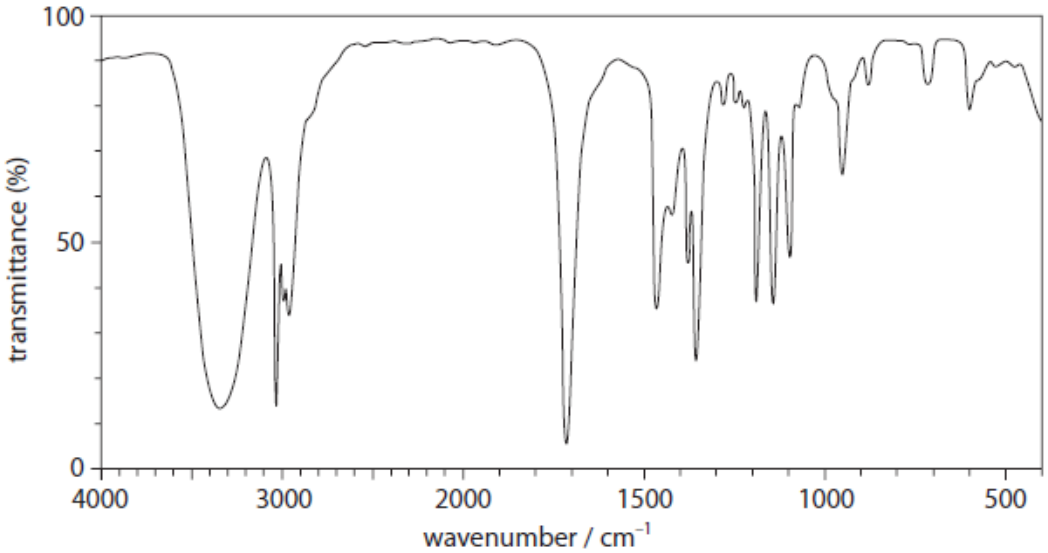
A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



The organic mixture was separated from the aqueous layer and dried.
The infrared spectrum of the organic mixture is shown.



(i) By reference to any relevant peak(s), deduce how the infrared spectrum shows that the mixture contains 3-methylbutan-2-one.

(2)

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(ii) From the infrared spectrum, the student concludes that the mixture contains another organic

compound.

The mixture is redistilled and the fraction that boils in the range 93–95°C is collected. The boiling temperature of 3-methylbutan-2-one is 94°C.

Predict any change(s) you would see in the infrared spectrum after redistillation, justifying your answer.

(2)

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(Total for question = 4 marks)

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 ☒.

This question is about the analysis of organic compounds.

X is an organic compound.

(i) The accurate relative atomic masses, A_r, of the four elements that could make up **X** are shown in the table.

Element	A_r
hydrogen, H	1.0078
carbon, C	12.0000
nitrogen, N	14.0031
oxygen, O	15.9949

X gives a molecular ion peak at $m / z = 100.0522$ on its mass spectrum.

Which is the molecular formula of **X**?

(1)

☒ **A** C_7H_{16}

☒ **B** $C_6H_{12}O$

☒ **C** $C_6H_{14}N$

☒ **D** $C_5H_8O_2$

(ii) The infrared spectrum of **X** contains major absorption wavenumber ranges at 3300–2500 cm^{-1}, 1725–1700 cm^{-1} and 1669–1645 cm^{-1}.

Identify the two functional groups in **X**.

(2)

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(iii) **X** has an unbranched carbon chain and does **not** exhibit geometric isomerism.

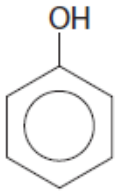
Draw the **skeletal formula** of **X**.

(1)

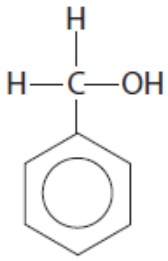
(Total for question = 4 marks)

Q11.

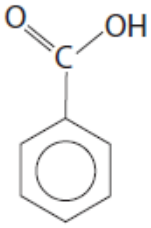
This is a question about the analysis of three aromatic substances with —OH groups.



phenol



phenylmethanol



benzoic acid

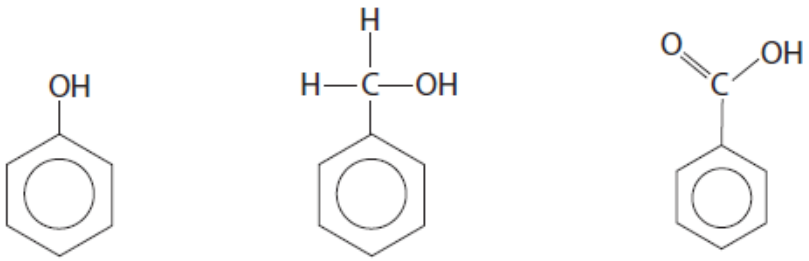
Write the equation for the **complete**combustion of phenol.
State symbols are not required.

(2)

(Total for question = 2 marks)

Q12.

This is a question about the analysis of three aromatic substances with —OH groups.



phenol phenylmethanol benzoic acid

When burned in air, these aromatic compounds undergo **incomplete** combustion.

(i) Calculate the percentage composition by mass of carbon in both phenylmethanol and benzoic acid.

(3)

(ii) Give the expected observation when these aromatic compounds undergo incomplete combustion.

(1)

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.....

(iii) Identify another **type** of organic compound which will also produce the same observation as in (ii).

(1)

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(iv) These combustion experiments must be carried out in a fume cupboard.



Explain why the front window of the fume cupboard must be below the safety line even with the exhaust fan switched on.

(2)

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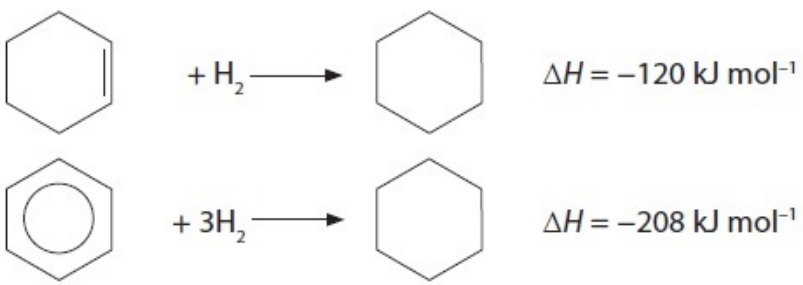
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(Total for question = 7 marks)

Q13. (a) Equations for the catalytic hydrogenation of cyclohexene and of benzene are shown below.



(i) What is the type of reaction in both of these hydrogenations?

(1)

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*(ii) The enthalpy of hydrogenation of benzene might be expected to be −360 kJ mol^{-1}. Explain why this is **not** the actual value.

(2)

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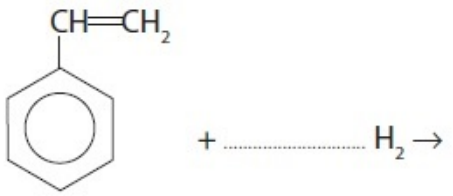
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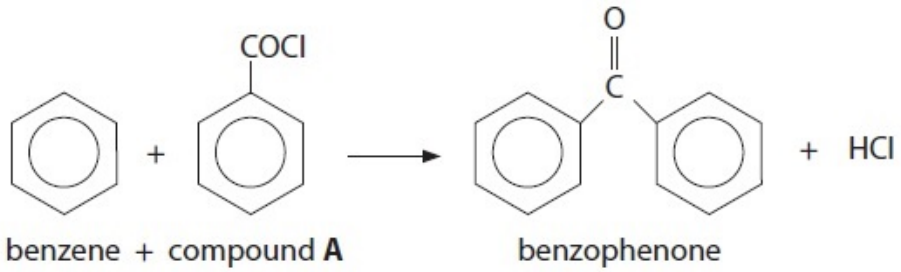
(iii) Complete the following equation for the total hydrogenation of phenylethene. Suggest a value for the enthalpy change of this reaction.

(3)



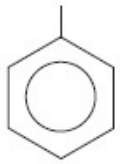
ΔH = ... kJ mol^{-1}

(b) The compound benzophenone is used as a sunscreen. It can be prepared from benzene, in the presence of aluminium chloride by the following reaction.



(i) Complete the diagram below by showing the **displayed** formula of the –COCl group in compound **A**.

(1)



(ii) Classify the type and mechanism of the reaction between benzene and compound **A**.

(1)

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(iii) Give the names of the two chemists associated with the type of reaction described in (b)(ii).

(1)

..... and .....

(iv) Give the mechanism for the reaction between benzene and compound **A** in the presence of an aluminium chloride catalyst.

Start by showing the equation for the generation of the species which then attacks the benzene ring.

(4)

Equation to show generation of species attacking the benzene ring:

Rest of the mechanism:

(v) Suggest the essential property of a substance that will be used as a sunscreen.

(1)

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.....

(c) (i) The identity of a sample of benzophenone can be confirmed by recording its infrared and proton nmr spectra.

Identify **two** different bonds that would produce an absorption in the infrared spectrum of benzophenone. Use the Data Booklet to suggest the wavenumber of each of these absorptions.

(4)

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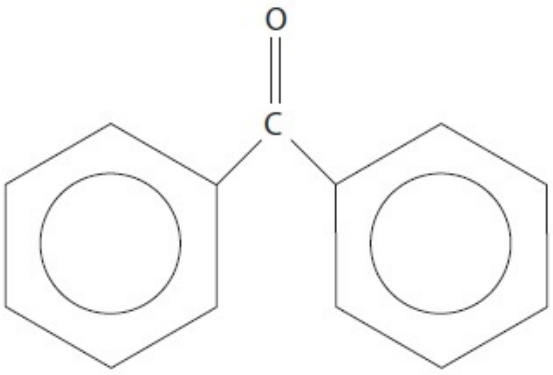
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(ii) In benzophenone there are three different hydrogen environments, X, Y and Z, that produce signals in the ratio 2:2:1 respectively in the proton nmr spectrum.

Identify, **on the structure drawn below**, the positions of all the hydrogen atoms in each environment, labelling the different environments **X**, **Y** and **Z**.

(2)



benzophenone

(Total for Question = 20 marks)

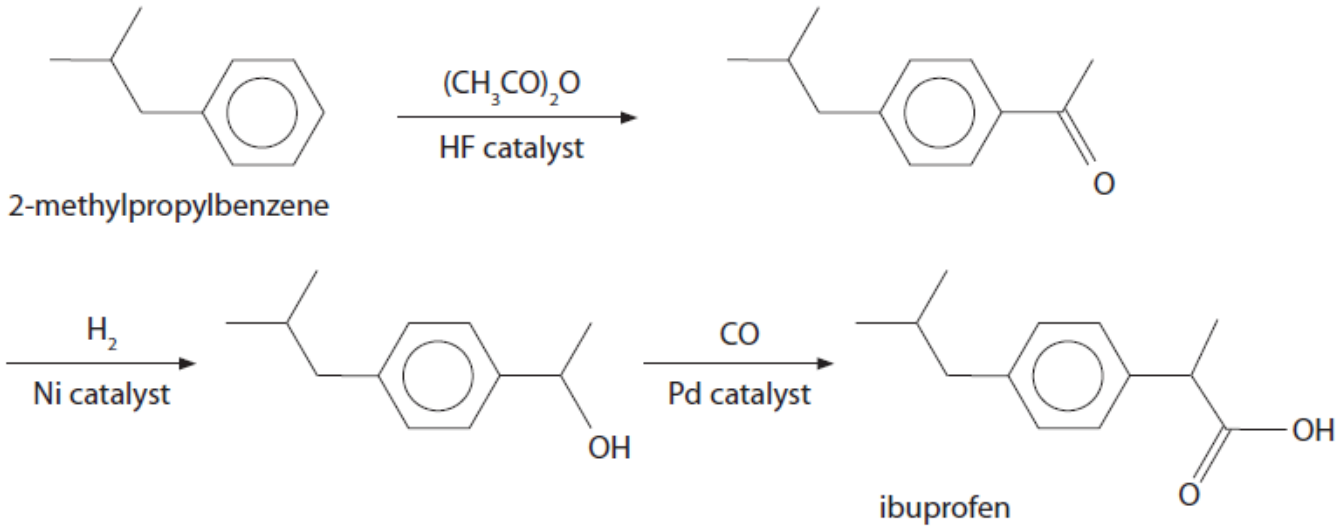
Q14. The total number of isomers of dibromobenzene, $C_6H_4Br_2$, containing a benzene ring is

- **A** 2
- **B** 3
- **C** 4
- **D** 5

(Total for Question = 1 mark)

Q15.

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



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

(1)

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

(1)

.....

.....

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

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

(1)

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

(3)

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

manufacture of ibuprofen.

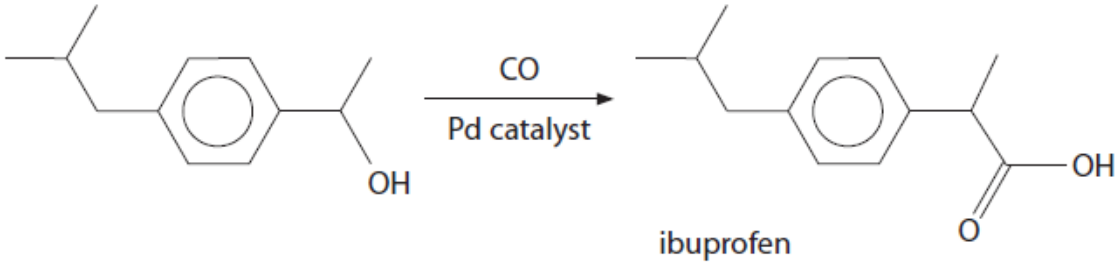
(1)

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



ibuprofen

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

(1)

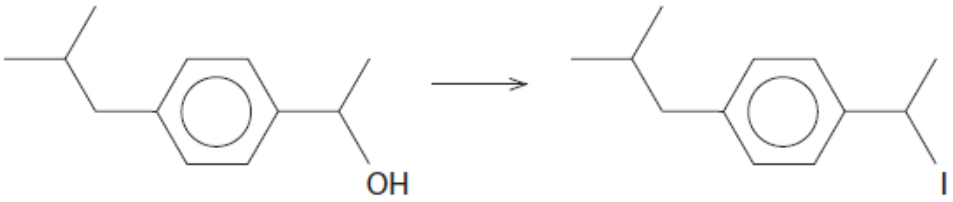
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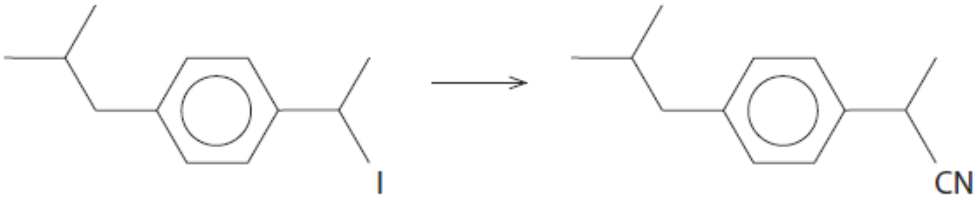
(ii) The preparation in part (c) can be carried out in a laboratory in three reactions.

(3)

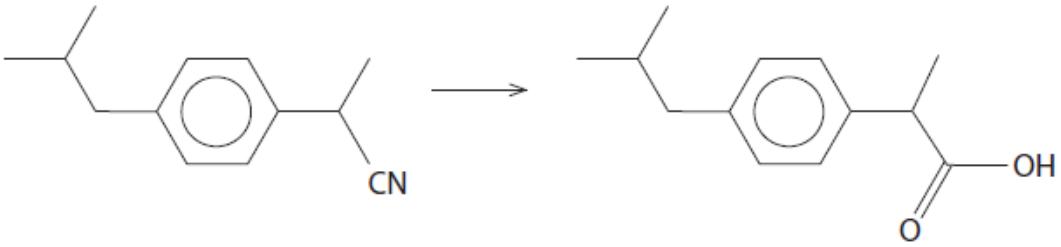
Reaction 1



Reaction 2



Reaction 3



Give:

The reagents for **Reaction 1**

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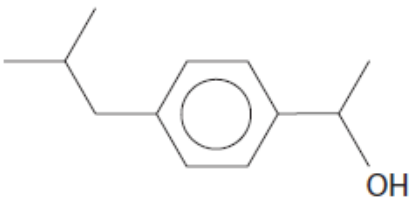
The reagents and conditions for **Reaction 3**

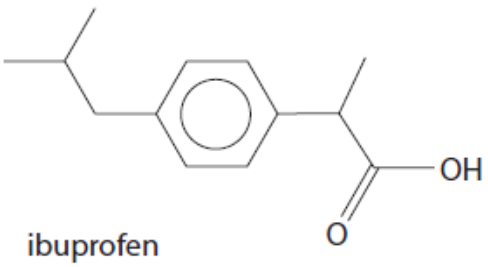
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(iii) Using your Data Booklet, explain how infrared spectroscopy can be used to distinguish between the two structures shown below.

(2)





ibuprofen

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

(i) Explain the term 'chiral molecule'.

(1)

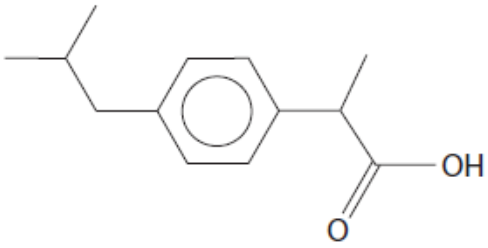
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(ii) Mark with an asterisk (*) the chiral centre on the structure of ibuprofen below.

(1)



(iii) Explain the term 'racemic mixture'.

(1)

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(Total for question = 16 marks)

Q16.

X-ray diffraction provides evidence that benzene molecules have

☒ **A** delocalized π electrons.

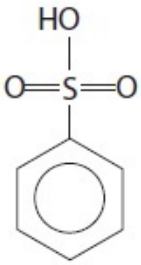
☒ **B** carbon–carbon bonds that are all the same length.

☒ **C** lower thermodynamic stability than molecules of 1,3,5-cyclohexatriene.

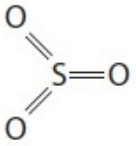
☒ **D** greater thermodynamic stability than molecules of 1,3,5-cyclohexatriene.

(Total for question = 1 mark)

Q17. (a) Benzenesulfonic acid (structure I) may be prepared from benzene. The reaction is a typical electrophilic substitution in which the electrophile is sulfur trioxide (structure II).



Structure I



Structure II

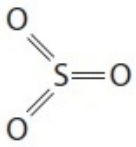
(i) Identify the reagent used as the source of sulfur trioxide in this preparation.

(1)

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(ii) On the formula of sulfur trioxide below, show the partial charges on each atom and explain how they arise.

(2)



Structure II

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(iii) Suggest why sulfur trioxide is an effective electrophile.

(1)

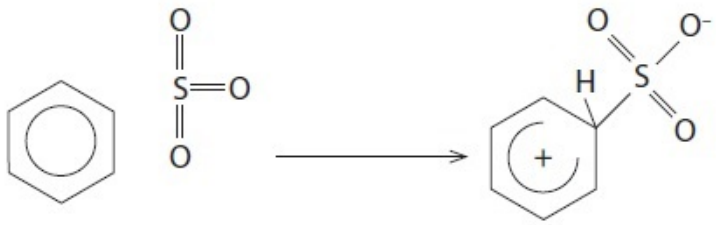
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(b) The mechanism for the electrophilic substitution reaction between benzene and sulfur trioxide to form benzenesulfonic acid is similar to that for the nitration of benzene.

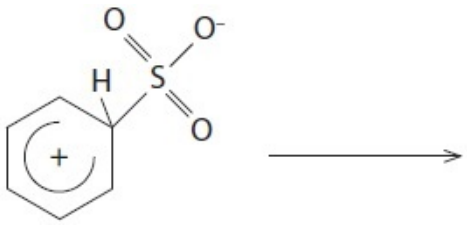
(i) Complete the first step of this mechanism by adding two curly arrows.

(2)



(ii) The mechanism for the formation of benzenesulfonic acid has two further steps. Complete the mechanism, showing curly arrows where appropriate.

(3)

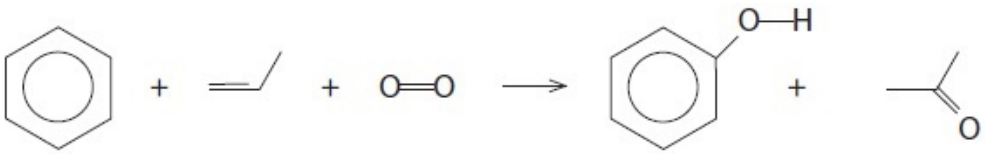


(c) At one time the main industrial use for benzenesulfonic acid was in the manufacture of phenol in a two-stage process. In the first stage, benzenesulfonic acid was reacted with sodium hydroxide forming an intermediate organic compound along with sodium sulfite, Na_2SO_3, and water. In the second stage, the intermediate organic compound was reacted with hydrochloric acid to form phenol.

(i) Write the two equations for the manufacture of phenol by this method. State symbols are not required.

(2)

(ii) Nowadays, phenol is manufactured using the Hock process which is summarised below.



Suggest why the Hock process is preferred.

(2)

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(Total for Question = 13 marks)

Q18.

Describe how the orbitals from carbon atoms interact to form the bonds in a benzene ring. You may include a labelled diagram to support your answer.

(3)

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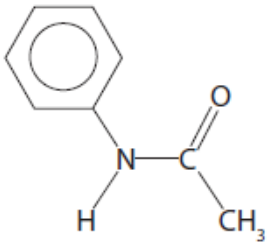
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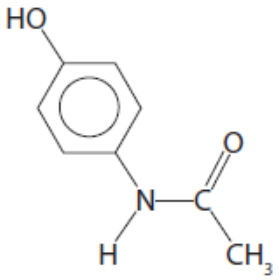
Q19.

Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.



Antifebrin

Paracetamol is structurally similar to Antifebrin, but has a hydroxy group attached directly to the benzene ring.



The bromination of the benzene ring in paracetamol occurs much more readily compared to the bromination of benzene.

Explain this increased reactivity.

(2)

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(Total for question = 2 marks)

Q20.

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

A sample of **Y** with a mass of 1.98 g was burned completely in excess oxygen.
The reaction formed 2.51 g of carbon dioxide, CO_2, and 0.69 g of water, H_2O.

Use these data to calculate the empirical formula of **Y**.

(4)

(Total for question = 4 marks)

Q21.

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

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

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

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

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

(5)

(Total for question = 5 marks)

Q22.

Titanium is the seventh most abundant metal in the Earth's crust and occurs principally as rutile (impure titanium(IV) oxide, TiO_2).

Early attempts to extract the metal from its oxide by reduction with heated carbon failed because the compound titanium carbide is formed. In 1910, however, pure titanium was made by heating titanium(IV) chloride with sodium.

Titanium has a high melting temperature and a density of 4.50 g cm^{-3}. Titanium is as strong as steel, but is about 40% less dense and is therefore suitable for use in the aircraft industry. Titanium metal resists corrosion as it has an impervious coating of titanium(IV) oxide. The metal adheres well to bone, is not rejected by the body and is in demand for the manufacture of replacement joints.

Titanium has two common oxidation states, +3 and +4. Solutions containing the $[Ti(H_2O)_6]^{3+}(aq)$ ion, such as titanium(III) chloride, are purple in colour and are readily oxidized by the oxygen in air to colourless titanium(IV) ions. An aqueous solution of titanium(III) chloride is a strong reducing agent. Titanium(IV) chloride, $TiCl_4$, is a colourless liquid with a boiling temperature of 136°C. This compound is used, in conjunction with organic compounds of aluminium, as a catalyst for the polymerization of propene to poly(propene). Titanium(IV) chloride is hydrolysed by water to give titanium(IV) oxide, TiO_2 and hydrogen chloride gas.

Titanium(IV) oxide is a white, non-toxic solid at room temperature. It is used as a white pigment in paint, largely replacing toxic lead compounds which were used previously. Titanium(IV) oxide reacts with concentrated sulfuric acid to form a salt and water. Titanium(IV) oxide also reacts with aqueous potassium hydroxide solution, under suitable conditions, to form a compound with formula $K_2Ti(OH)_6$.

(a) (i) Write the equation for the reaction which occurs during the manufacture of titanium from titanium(IV) chloride as described in the article above. State symbols are not required.

(1)

(ii) Explain, by stating the changes of oxidation numbers, why the reaction in (i) is classified as a redox reaction.

(2)

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(b) Complete the electronic configurations of

(2)

Ti [Ar] .....

Ti^{3+} [Ar] .....

Ti^{4+} [Ar] .....

(c) Use your answer to (b) to explain why titanium is

(i) a *d*-block element

(1)

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(ii) a transition element

(1)

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*(d) (i) Explain why the hexaaquatitanium(III) ion, $[Ti(H_2O)_6]^{3+}$, is coloured.

(3)

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(ii) Explain briefly why titanium(IV) compounds are colourless.

(1)

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*(e) (i) Titanium(IV) oxide has a melting temperature of 1830 °C. Use this data, plus information

in the article at the start of the question, to compare the structure and bonding in titanium(IV) oxide with that in titanium(IV) chloride. Hence explain why these two compounds change state at very different temperatures.

(4)

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(ii) Give the term used to describe an oxide, such as titanium(IV) oxide, which can react with both acids and bases.

(1)

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(iii) Using information in the article, write the equation for the reaction between titanium(IV) oxide and aqueous potassium hydroxide solution. State symbols are not required.

(1)

(iv) Titanium(IV) chloride is one of the catalysts used in the polymerization of propene to form poly(propene).

Give the displayed formula of the repeat unit of poly(propene).

(1)

(f) The concentration of a solution of titanium(III) chloride can be determined by titration with a solution of hydrogen peroxide, H_2O_2, in acidic conditions. The end-point of the reaction is when the solution of titanium(III) chloride in the flask goes colourless.

(i) Complete the ionic half-equation to show the reduction of hydrogen peroxide.

(1)

$$H_2O_2 + 2H^+ + \text{.....} \rightarrow \text{.....}$$

*(ii) One mole of hydrogen peroxide reacts with two moles of titanium(III) chloride.

In an experiment, 5.00 cm^3 of a sample of titanium(III) chloride solution was transferred to a volumetric flask and made up to 250 cm^3 of an aqueous solution. A 25.0 cm^3 portion of this diluted solution was acidified and titrated with a 0.0200 mol dm^{-3} solution of hydrogen peroxide, H_2O_2. The mean titre was 22.50 cm^3.

Calculate the concentration of the **original** titanium(III) chloride solution, in mol dm^{-3}.

(3)

(iii) Use information in the article to suggest why this titration gives a value that is lower than the true value for the concentration of titanium(III) chloride solutions.

(1)

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(Total for Question = 23 marks)

Q23.

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

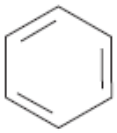
Combustion analysis of 1.56 g of 2-phenylethyl propanoate, in a laboratory, produced 4.26 g of CO_2(g) and 1.10 g of H_2O(l).

Show that the data is consistent with the molecular formula of 2-phenylethyl propanoate, $C_{11}H_{14}O_2$.

(4)

Q24.

Benzene is sometimes represented as Structure **X**, shown below, called a Kekulé structure after the chemist who suggested it.



Structure **X**

(a) What structural feature of benzene shows that Structure **X** is not an accurate representation?

(1)

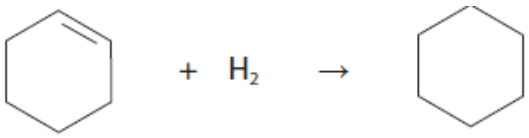
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(b) The enthalpy changes for the formation of cyclohexane from cyclohexene and from the actual structure of benzene are given below.

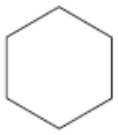


$+ \ H_2 \rightarrow$

$\Delta H = -118 \text{ kJ mol}^{-1}$



$+ \ 3H_2 \rightarrow$



$\Delta H = -205 \text{ kJ mol}^{-1}$

(i) Use the necessary data to estimate the enthalpy change for the theoretical conversion of Structure **X** to cyclohexane.

(1)

(ii) On the enthalpy level diagram below, draw labelled horizontal lines to show the relative enthalpies of the actual structure of benzene, Structure **X** and cyclohexane. Add an arrow to show the enthalpy change from Structure **X** to benzene and calculate the value of this enthalpy change in kJ mol^{-1}. Write this value next to your arrow.

(2)



*(iii) Explain the difference in the arrangement of the electrons between benzene and Structure **X**.

(2)

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(Total for question = 6 marks)

Q25.

(i) State **two** observations which would be made when phenol reacts with bromine water.

(2)

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(ii) Write the equation for this reaction showing the structure of the organic product.

(2)

*(iii) Explain why phenol can react with either bromine or with bromine water without a catalyst.

(2)

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Q26.

Separate 0.1 mol dm^{-3} aqueous solutions of ammonia, methylamine and phenylamine were prepared. Which of the following sequences shows the solutions in order of **increasing** pH?

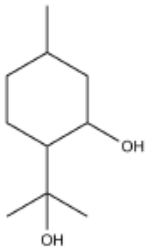
- ☒ **A** phenylamine, methylamine, ammonia
- ☒ **B** phenylamine, ammonia, methylamine
- ☒ **C** methylamine, ammonia, phenylamine
- ☒ **D** methylamine, phenylamine, ammonia

(Total for question = 1 mark)

Q27.

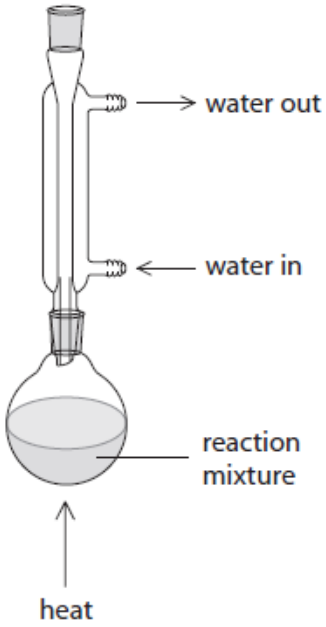
Alcohols contain the hydroxyl functional group. They can be oxidised using appropriate reagents and conditions.

Alcohol **Y** contains two hydroxyl groups.

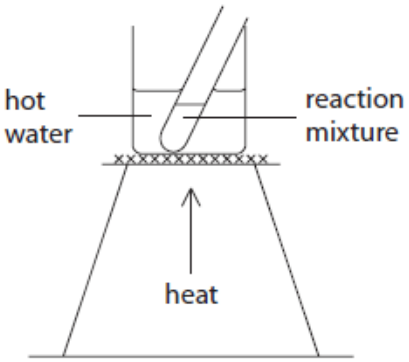


Alcohol **Y** can be oxidised by heating it with sodium dichromate(VI) solution and sulfuric acid.

*(a) A student suggested two possible techniques for heating the reaction mixture.



Technique A



Technique B

Evaluate all aspects of the two techniques and justify which one is more appropriate to just show that alcohol **Y** is able to be oxidised.

(6)

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(b) Explain, using information from the Data Booklet, whether hydrochloric acid is a suitable alternative to sulfuric acid in the reaction mixture.

(2)

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(c) Draw the **skeletal** formula of the organic product formed by the oxidation of alcohol **Y**.

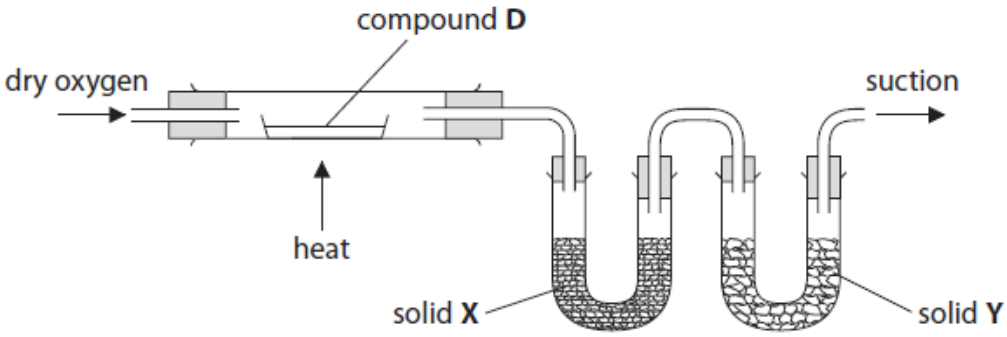
(1)

(Total for question = 9 marks)

Q28.

Organic compound **D** contains the elements carbon, hydrogen, oxygen and nitrogen only.

A sample of **D** was burned completely in the apparatus shown.
Solid **X** absorbed the water formed in the combustion.
Solid **Y** absorbed the carbon dioxide.



(i) The masses of solids **X** and **Y** increased during the experiment.

Explain the effect, if any, on the changes in mass of **X** and **Y** if the oxygen gas was not dry.

(3)

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(ii) On combustion in dry oxygen, 3.36 g of **D** produced 0.72 g of water and 5.28 g of carbon dioxide.

This sample of **D** also contained 0.56 g of nitrogen.

Use these data to calculate the empirical formula of compound **D**.

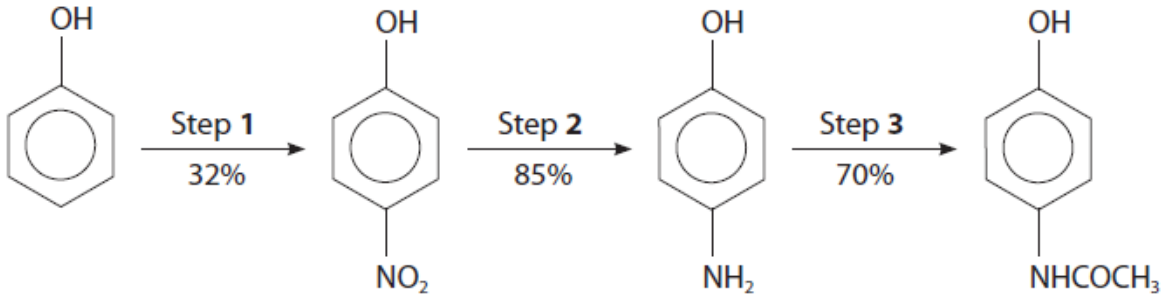
You **must** show your working.

(5)

(Total for question = 8 marks)

Q29.

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



phenol paracetamol

Explain why amino acids such as glycine are crystalline solids at room temperature.

(2)

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(Total for question = 2 marks)

Q30.

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

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

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

(5)

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

State what can be deduced from each of these results.

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

(1)

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

(1)

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

(1)

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

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

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

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

(7)

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(Total for question = 15 marks)

Q31. A 50 cm^3 sample of a gaseous hydrocarbon required exactly 250 cm^3 of oxygen for complete combustion. A volume of 150 cm^3 of carbon dioxide was produced.

[All volume measurements were made at the same temperature and pressure.]

Which of the following is the correct formula of the hydrocarbon?

☒ **A** C_3H_4

☒ **B** C_3H_8

☒ **C** C_5H_{10}

☒ **D** C_5H_{12}

(Total for Question = 1 mark)

Q32.

This question is about hydrocarbons.

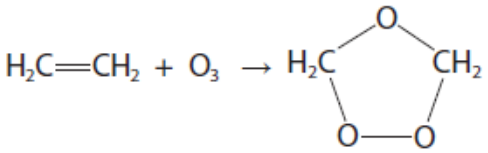
0.28 g of a gaseous hydrocarbon, **J**, was burned in excess oxygen.
0.88 g of carbon dioxide and 0.36 g of water were formed.
The volume of 0.28g of **J** at 1.01×10^5 Pa and 298 K is 123 cm^3.

Use this information to show that the molecular formula of J is C_4H_8.

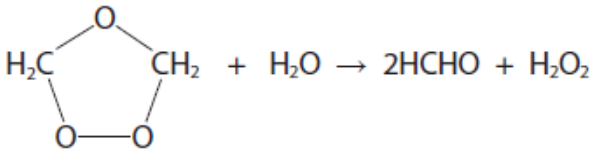
(4)

Q33.

Ozone reacts with an alkene, such as ethene, dissolved in an organic solvent to form an ozonide.



When hydrolysed by warming with water and zinc dust, the ozonide splits up to form carbonyl compounds.



These reactions can be used to find the position of a double bond in an alkene.

The hydrocarbon **J** was treated with ozone and the product was hydrolysed by warming with water and zinc dust.
Two different carbonyl compounds, **K** and **L**, were formed and separated.

The mass spectrum of compound **K** showed a molecular ion peak at *m/z* 30.

The mass spectrum of compound **L** showed a molecular ion peak at *m/z* 58 and there were 2 peaks on the ^{13}C NMR spectrum.

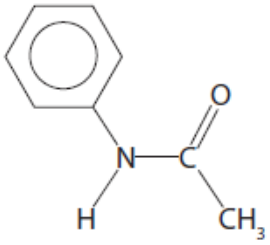
Use this information to deduce the identities of the carbonyl compounds **K** and **L** and hence the hydrocarbon **J**. Justify your answers.

Write equations for the reaction between hydrocarbon **J** and ozone and for the hydrolysis of the product.

(5)

Q34.

Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.



Antifebrin

Some of the following reagents can be used to produce Antifebrin from benzene.

- Aluminium chloride
- Ammonia, concentrated
- Benzene
- Ethanal
- Ethanoic acid
- Ethanol
- Ethanoyl chloride
- Hydrochloric acid, concentrated
- Hydrochloric acid, dilute
- Iron
- Nitric acid, concentrated
- Nitric acid, dilute
- Propanone
- Sodium chloride
- Sulfuric acid, concentrated
- Tin

Selecting from only these reagents, devise a **three-step** synthetic pathway to convert benzene into Antifebrin. You should include the structures of the two intermediate compounds and the reaction conditions.

(5)

(Total for question = 5 marks)

Q35.

* Devise a synthesis of butan-2-ol using ethanol as the only organic starting material and involving the formation of a Grignard reagent. Include the essential reagents and conditions for the reactions and give the structures of the intermediates.

(6)

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Q36.

This question is about aluminium chloride.

At high temperatures, aluminium chloride exists as $AlCl_3$ molecules.

(i) Draw a dot-and-cross diagram of an aluminium chloride molecule, $AlCl_3$. Show the outer shell electrons only.

(1)

(ii) Predict the shape of an $AlCl_3$ molecule and the Cl−Al−Cl bond angle.

(2)

Shape of $AlCl_3$	
Cl–Al–Cl bond angle	

(iii) Aluminium chloride is used as a catalyst in the alkylation of benzene.

Draw the mechanism for the reaction between benzene and chloromethane using aluminium chloride as the catalyst.
Include an equation for the formation of the electrophile, and any relevant curly arrows.

(4)

(Total for question = 7 marks)

Q37.

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

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

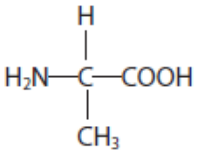
Draw the mechanism for the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia to form the primary amine. Include curly arrows and relevant lone pairs.

(3)

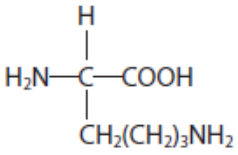
(Total for question = 3 marks)

Q38.

Alanine and lysine are amino acids.



alanine



lysine

(a) Draw the structure of a dipeptide formed when one molecule of alanine reacts with one molecule of lysine.

(1)

(b) The dipeptide formed in part (a) is hydrolysed under **acidic** conditions and the resulting mixture is analysed by column chromatography. The column uses a polar stationary phase.

Explain why lysine leaves the chromatography column after alanine.

(2)

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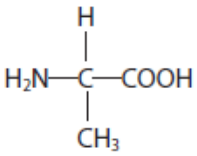
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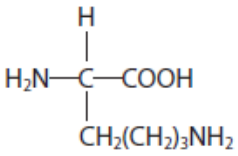
(Total for question = 3 marks)

Q39.

Alanine and lysine are amino acids.



alanine



lysine

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

(3)

aqueous sodium hydroxide, NaOH(aq)

excess dilute hydrochloric acid, HCl(aq)

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

(Total for question = 3 marks)

Q40.

When benzene reacts with fuming sulfuric acid, which species is most likely to be the electrophile?

- ☒ **A** H_3O^+
- ☒ **B** SO_3
- ☒ **C** HSO_4^-
- ☒ **D** SO_4^{2-}

(Total for question = 1 mark)

Q41.

This question is about arenes.

Methylbenzene reacts with a mixture of concentrated nitric and sulfuric acids to form 1-methyl-4-nitrobenzene.



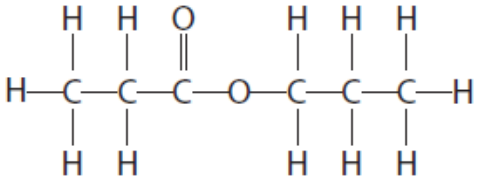
Give the mechanism for the reaction, including an equation for the formation of the electrophile.

(4)

Q42.

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

Propyl propanoate has the structure shown.



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

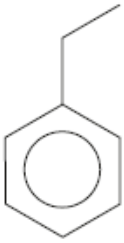
Include the reagents for each step in the synthesis, and the names or structures of the intermediate compounds.

(5)

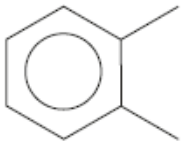
(Total for question = 5 marks)

Q43.

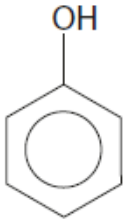
This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.



ethylbenzene



xylene



phenol

Ethylbenzene can be formed by the reaction of a chloroalkane with benzene, catalysed by aluminium chloride, $AlCl_3$.

(i) Draw the **displayed** formula of the chloroalkane required for this reaction.

(1)

(ii) Draw the mechanism for this reaction.

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

(5)

(iii) Explain whether phenol is likely to be less or more reactive than benzene with

the chloroalkane from (i).

(3)

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(Total for question = 9 marks)

Q44.

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

The following steps were carried out.

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

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

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

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

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

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

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

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

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

In Step **2** there is a pressure build-up in the separating funnel.

Describe how you would lower the pressure.

(1)

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.....

.....

(Total for question = 1 mark)

Q45.

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

The following steps were carried out.

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

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

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

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

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

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

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

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

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

State why, in Step **4**, the aqueous layer was the lower of the two layers.

(1)

.....

(Total for question = 1 mark)

Q46.

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

The following steps were carried out.

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

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

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

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

Step **5** The ether layer in the separating funnel was washed with deionised water

and the washings added to the beaker.

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

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

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

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

Give a reason why, in Step **5**, the ether layer was washed with deionised water.

(1)

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.....

(Total for question = 1 mark)

Q47.

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

The following steps were carried out.

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

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

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

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

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

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

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

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

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

Draw a diagram of the apparatus used in Step **7** to filter under reduced pressure.

(2)

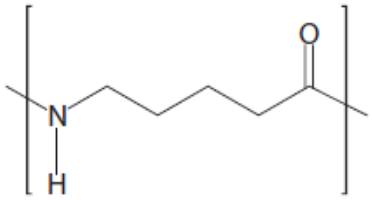
(Total for question = 2 marks)

Q48.

This is a question about polymerisation.

Deduce the single monomer that could be used to produce the polyamide shown.

(1)



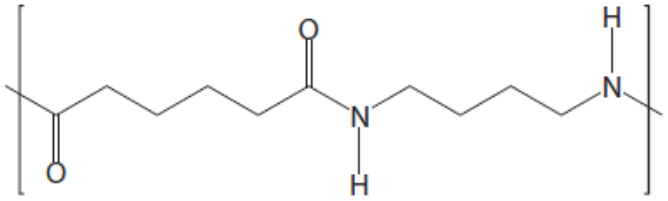
(Total for question = 1 mark)

Q49.

This is a question about polymerisation.

Deduce the two monomers needed to produce the polyamide shown.

(2)

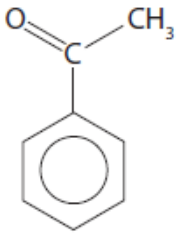


and

(Total for question = 2 marks)

Q50.

Phenylethanone is an ingredient in many types of chewing gum.



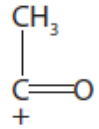
One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, CH_3COCl.

(i) Write the equation for the formation of the electrophile, CH_3CO^+, from ethanoyl chloride using the catalyst aluminium chloride.

(1)

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction between this electrophile and benzene to produce phenylethanone. Include the regeneration of the catalyst.

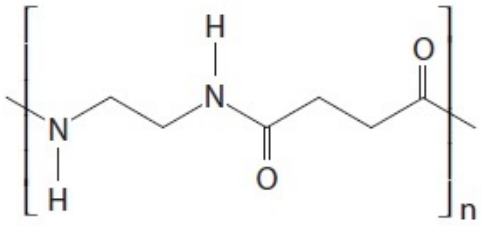
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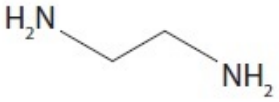
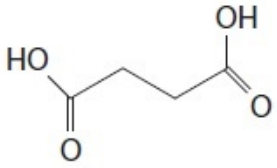
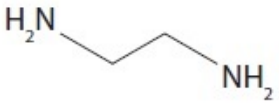
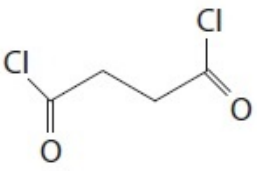
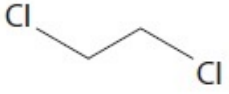
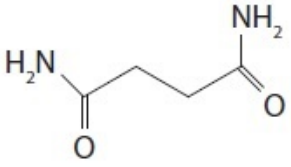
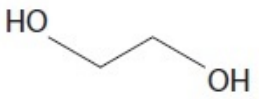
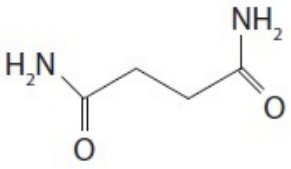


(Total for question = 5 marks)

Q51. The structure below shows the repeating pattern of a polymer.



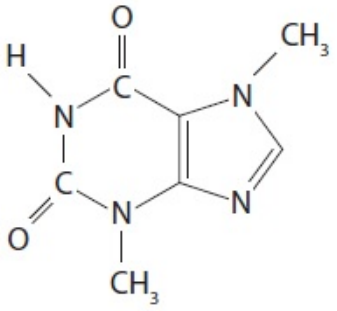
Which of the following pairs of compounds could react **rapidly** to form this polymer?

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

(Total for Question = 1 mark)

Q52.

The compound shown below is found in cocoa beans and in chocolate. Which of the groups listed is **not** present in its structure?



☒ **A** Alkyl

☒ **B** Amide

☒ **C** Amine

☒ **D** Ketone

(Total for question = 1 mark)

Q53.

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 ☒.

Gentian violet is a purple crystalline solid used as an antifungal treatment.

It can be synthesised from dimethylphenylamine, $C_6H_5N(CH_3)_2$.

The dimethylphenylamine used in the synthesis can be made by the stepwise reaction of phenylamine with chloromethane.

Step **1** $2C_6H_5NH_2 + CH_3Cl \rightarrow C_6H_5NH(CH_3) + C_6H_5NH_3^+Cl^-$

Step **2** $2C_6H_5NH(CH_3) + CH_3Cl \rightarrow C_6H_5N(CH_3)_2 + C_6H_5NH_2^+(CH_3)Cl^-$

The reaction mechanism for Step **1** between phenylamine and chloromethane is the same as that in the reaction between ammonia and chloromethane.

(i) What is the reaction type and mechanism in Step **1**?

(1)

☒ **A** electrophilic addition

☒ **B** electrophilic substitution

☒ **C** nucleophilic addition

☒ **D** nucleophilic substitution

(ii) Draw the mechanism for the reaction in Step **1**.

Include curly arrows, and relevant lone pairs and dipoles.

(4)

(iii) Describe, in outline, how a sample of a solid, such as gentian violet, is purified by recrystallisation.

Specific details of the solvent used are not required.

(4)

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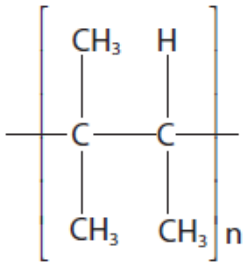
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(Total for question = 9 marks)

Q54.



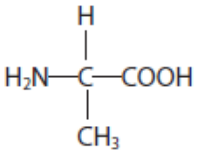
Which is the IUPAC name for the monomer which reacts to make the polymer shown above?

- ☒ **A** 2-methylbut-1-ene
- ☒ **B** 2-methylbut-2-ene
- ☒ **C** 1,2-dimethylpropene
- ☒ **D** 1,1,2-trimethylethene

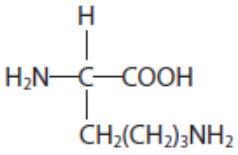
(Total for question = 1 mark)

Q55.

Alanine and lysine are amino acids.



alanine



lysine

Give the systematic (IUPAC) name for **lysine**.

(1)

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(Total for question = 1 mark)

Q56.

Some organic compounds contain metals.

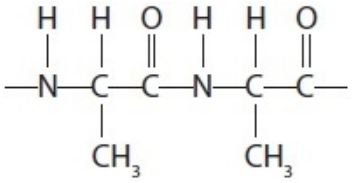
Grignard reagents contain a metal.

Discuss how Grignard reagents are formed and used in adding one or more carbon atoms to the carbon chain in 1-bromopropane to produce primary, secondary and tertiary alcohols and a carboxylic acid.

Include a suitable example for each reaction and give reagents, conditions and products. You may include equations in your answer.

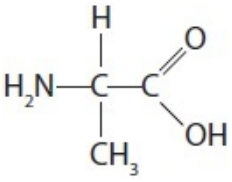
(Total for question = 6 marks)

Q57. A section of the polypeptide made from a single amino acid is shown below.

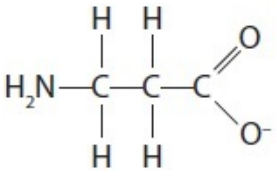


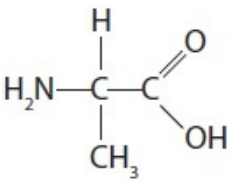
The polypeptide was heated with excess dilute sodium hydroxide solution until no further change took place.

Which of the following products is formed?

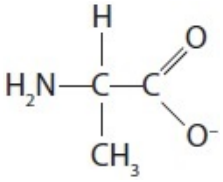


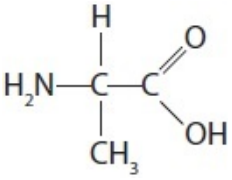
A



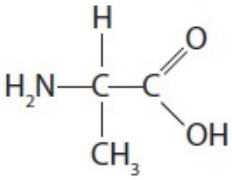


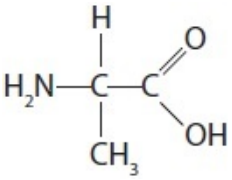
B



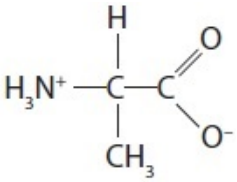


C





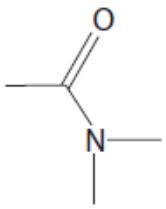
D



(Total for Question = 1 mark)

Q58.

The skeletal formula of an organic compound is shown below.



This compound is

☒ **A** an amino acid.

☒ **B** an amide.

☒ **C** a primary amine.

☒ **D** a secondary amine.

(Total for question = 1 mark)

Q1.

Tests are carried out on aqueous solutions of two salts, **X** and **Y**.

X contains one cation and one anion.

The observations for each test are recorded in the table.

(i) Complete the table by writing the names or formulae of the species.

(2)

Test	Observation	Inference
Test 1 Add aqueous sodium hydroxide to an aqueous solution of **X**	A green precipitate forms The precipitate turns brown on the top after a few minutes	The cation in **X** is .....
Test 2 To an aqueous solution of **X**, add dilute hydrochloric acid followed by aqueous barium chloride	A white precipitate forms	The anion in **X** is .....

(ii) Write the ionic equation for the reaction between the cation in **X** and aqueous sodium hydroxide in **Test 1**. Include state symbols.

(2)

(iii) Give a reason why the green precipitate turns brown on the top after a few minutes.

(1)

.....

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(iv) Give a reason why dilute hydrochloric acid is needed in **Test 2**.

(1)

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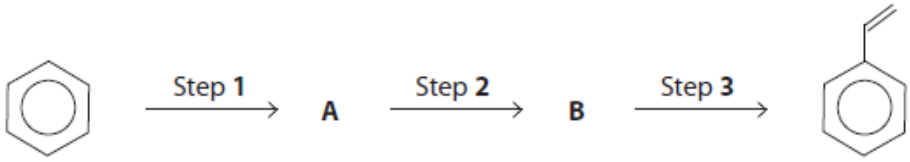
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(Total for question = 6 marks)

Q2.

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



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

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

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

(5)

(Total for question = 5 marks)

Q3.

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

The following steps were carried out.

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

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

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

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

Step **5** The ether layer in the separating funnel was washed with deionised water

and the washings added to the beaker.

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

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

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

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

The melting temperature range of the purified benzoic acid in Step **9** was 116–121 °C.

Compare this result with the literature value, giving a reason for any differences.

(2)

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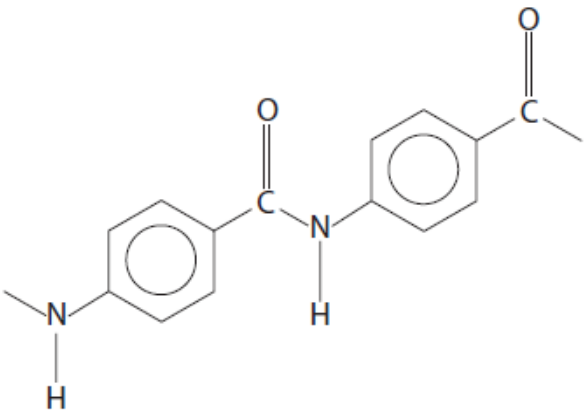
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(Total for question = 2 marks)

Q4.

Part of the structure of a polyamide is shown.

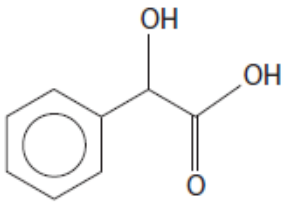


Draw the structure of a single monomer that could be used to form this polyamide.

(1)

Q5.

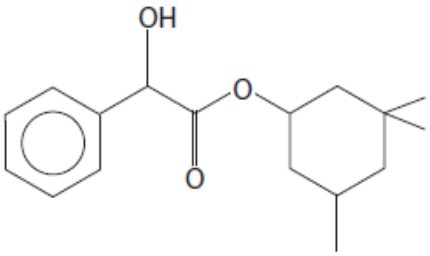
The compound mandelic acid is used in cosmetic skin peels.



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

(3)

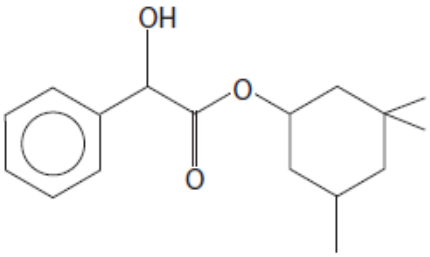
(b) The compound cyclandelate is used to treat a condition called Raynauld's disease, which affects blood flow to the body's extremities, such as fingers and toes. The structure of cyclandelate is



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

(2)

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



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

(4)

(Total for question = 9 marks)

Q6.

Compound **C** is a pink crystalline solid containing two cations and one anion.

Three tests were carried out on **C**. The observation made for each test was recorded in the table.

(i) Complete the statements in the inference column by writing the names or formulae of the species.

(6)

Test	Observation	Inference
Test 1 Aqueous sodium hydroxide was added to solid **C** and the mixture warmed The gas evolved was tested with damp red litmus paper	The red litmus paper turned blue	The gas evolved was ..... One of the cations in **C** is .....
Test 2 Concentrated hydrochloric acid was added to an aqueous solution of **C**	The pink solution turned blue	The other cation in **C** is ..... The formula of the complex ion in the blue solution is .....
Test 3 Dilute hydrochloric acid and aqueous barium chloride were added to an aqueous solution of **C**	A white precipitate formed	The white precipitate is ..... The anion in **C** is .....

(ii) Use the results of the tests in (i) to give a formula of **C**.

Do not include water of crystallisation.

(1)

.....

(Total for question = 7 marks)

Q7.

Benzene is nitrated using a mixture of concentrated nitric and sulfuric acids. The sulfuric acid

☒ **A** acts as a solvent for the benzene and the nitric acid.

☒ **B** protonates the benzene to speed up the reaction.

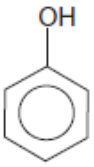
☒ **C** protonates the nitric acid which acts as a base.

☒ **D** reacts with the benzene to form a benzenesulfonic acid intermediate.

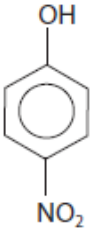
(Total for question = 1 mark)

Q8.

Phenol is a feedstock in the production of many organic molecules.

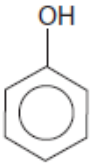


Phenol can be nitrated to produce 4-nitrophenol.



(i) The mechanisms of the nitration of phenol and of benzene are similar. Complete the diagram, using curly arrows, to show a possible mechanism for the reaction between the electrophile, NO_2^+, and phenol to produce 4-nitrophenol.

(3)



NO_2^+

(ii) What is the mass, in grams, of 4-nitrophenol produced from 0.94 g of phenol if the yield of this isomer is 15%?

(1)

☒ **A** 0.14

☒ **B** 0.21

☒ **C** 0.68

☒ **D** 1.39

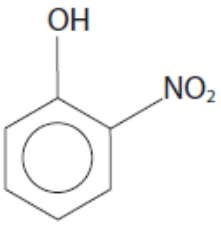
(iii) Draw **two** structural isomers of 4-nitrophenol which have a benzene ring.

(1)

(Total for question = 5 marks)

Q9.

Phenol reacts with dilute nitric acid at room temperature to form a mixture of 2-nitrophenol and 4-nitrophenol.



2-nitrophenol



4-nitrophenol

(i) Explain why phenol reacts with nitric acid more readily than benzene.

(2)

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(ii) Suggest an explanation for 2-nitrophenol being less soluble in water than 4-nitrophenol.

(2)

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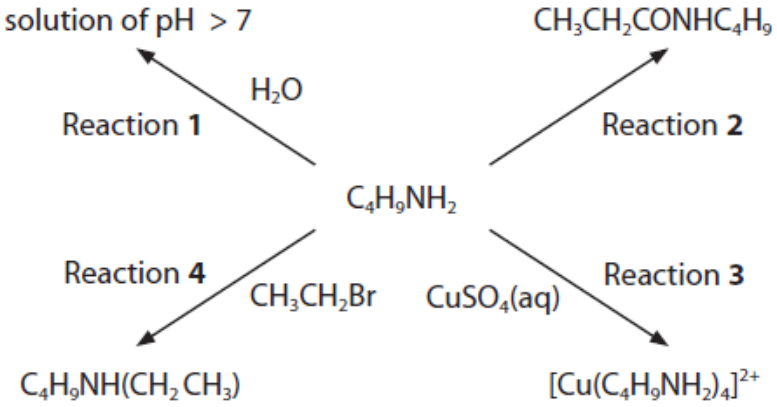
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Q10.

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 ☒ .

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

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



(i) What is the type and mechanism of the reaction in Reaction **4**?

(1)

☒ **A** electrophilic addition

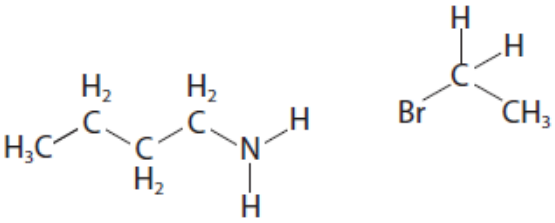
☒ **B** electrophilic substitution

☒ **C** nucleophilic addition

☒ **D** nucleophilic substitution

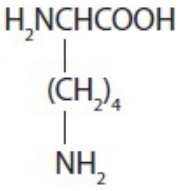
(ii) Complete the diagram to show the mechanism for Reaction **4**.
Include curly arrows, and relevant lone pairs and dipoles.

(4)

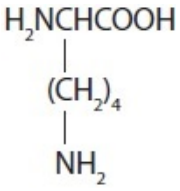


(Total for question = 5 marks)

Q11. Which of the following amino acids is optically active and produces an approximately neutral solution when dissolved in water?

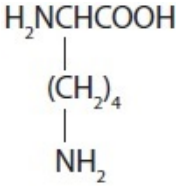


A H_2NCH_2COOH

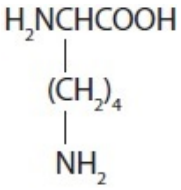


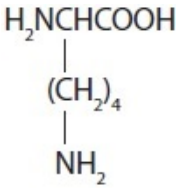
B



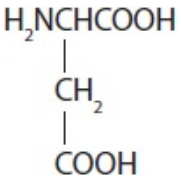


C





D

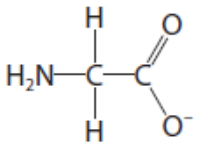


(Total for Question = 1 mark)

Q12.

Some organic compounds contain metals.

Glycinate ions are formed from the amino acid glycine.



glycinate ion

(i) Explain the effect, if any, of an aqueous solution containing glycinate ions on plane-polarised monochromatic light.

(2)

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

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

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

(2)

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

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

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

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

Discuss possible reasons for the yields obtained by these students.

(4)

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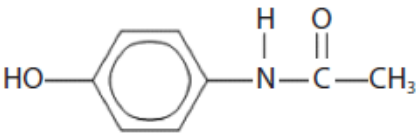
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(Total for question = 8 marks)

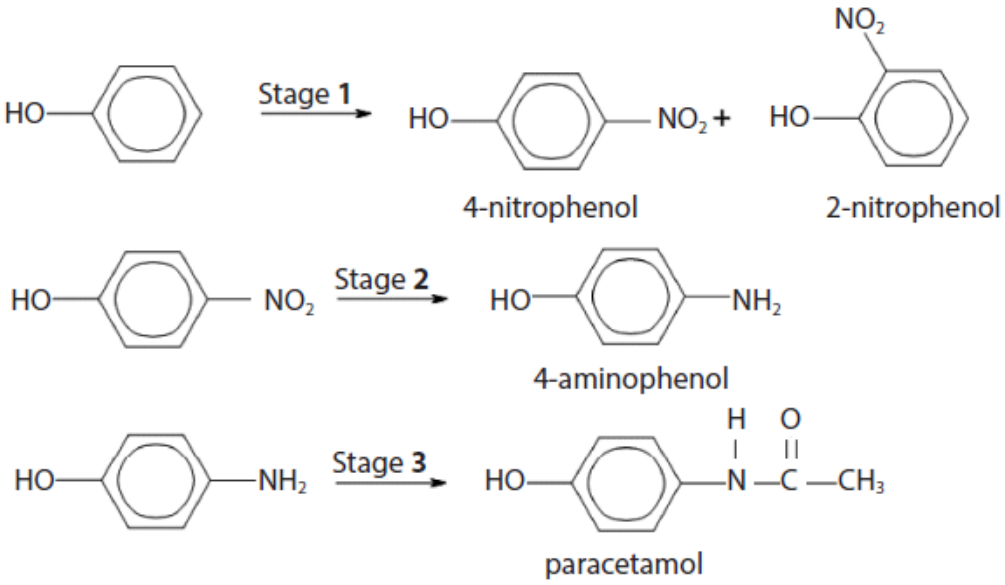
Q13.

This question is about the preparation and analysis of paracetamol.



paracetamol

Paracetamol may be prepared from phenol in three stages.

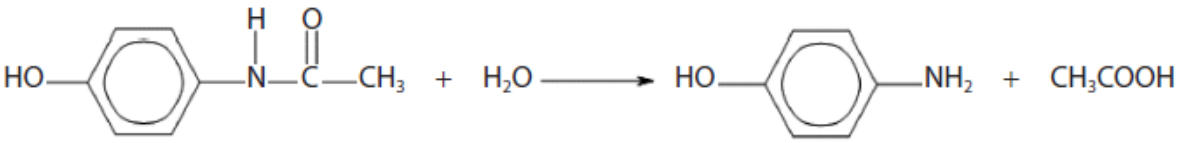


The percentage by mass of paracetamol in three brands of paracetamol tablets are shown in the table.

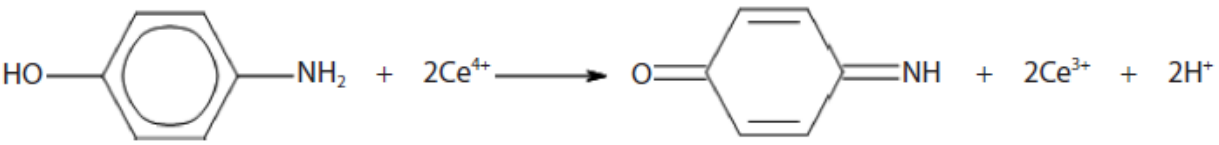
Brand of tablet	Percentage by mass of paracetamol
P	92.1
Q	93.6
R	99.7

The amount of paracetamol in a tablet can be determined using a titration with cerium(IV) ions.

The tablets are crushed and then hydrolysed in acid to form 4-aminophenol.



4-aminophenol is oxidised by cerium(IV) ions.



A tablet from one of the three brands of paracetamol was analysed following the outline procedure.

- one of the tablets was crushed and 0.500 g of the powder was added to dilute sulfuric acid
- the mixture was heated under reflux until the hydrolysis was complete

- the solution was made up to 100.0 cm^3 in a volumetric flask
- 25.0 cm^3 portions of the solution were titrated against 0.100 mol dm^{-3} Ce^{4+} using ferroin as indicator

Result

The mean titre was 16.50 cm^3.

(i) Give the molecular formula of paracetamol.

(1)

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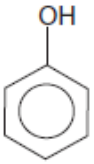
(ii) Determine, by calculation, which brand of tablet was analysed.

(5)

(Total for question = 6 marks)

Q14.

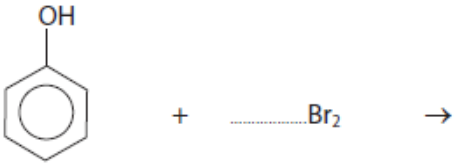
Phenol is a feedstock in the production of many organic molecules.



Phenol reacts with bromine water.

(i) Complete the equation for the reaction of phenol with excess bromine water, using the **skeletal** formula of the organic product.

(2)



(ii) Compare and contrast the bromination of phenol with the bromination of benzene.

(3)

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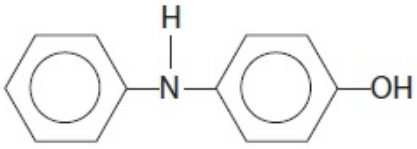
(Total for question = 5 marks)

Q15.

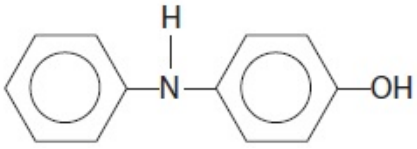
Phenylamine (aniline), $C_6H_5NH_2$, may be prepared from nitrobenzene, $C_6H_5NO_2$.

(a) The reagent normally used for this reaction is

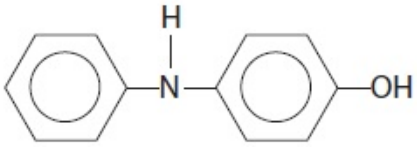
(1)



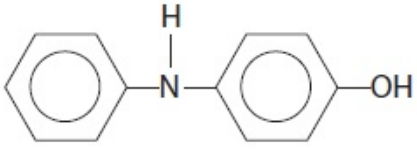
A lithium tetrahydridoaluminate(III) (lithium aluminium hydride) in ether.



B concentrated ammonia in ethanol.



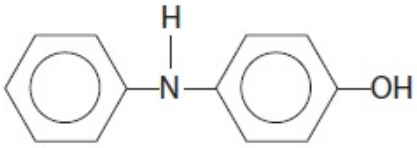
C potassium dichromate(VI) in sulfuric acid.



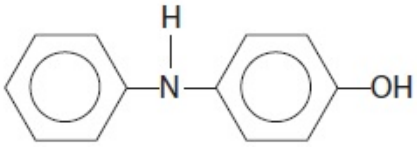
D tin in concentrated hydrochloric acid.

(b) The phenylamine is separated from the reaction mixture by

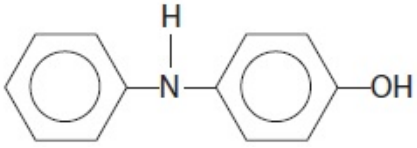
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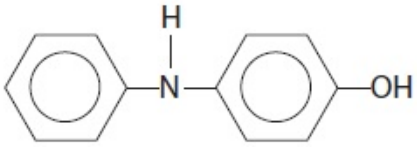
A paper chromatography.



B steam distillation.



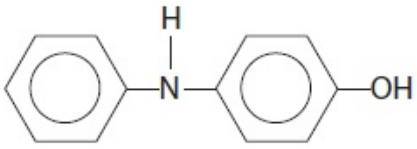
C filtration.



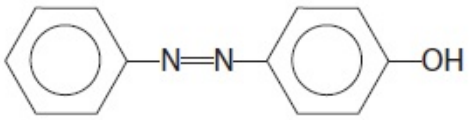
D recrystallization.

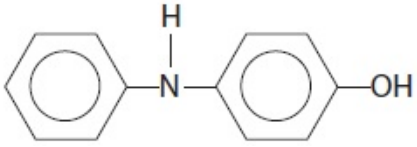
(b) One test for phenylamine is to convert it into a diazonium ion which is then reacted with phenol to form an azo dye. The structure of this dye is

(1)

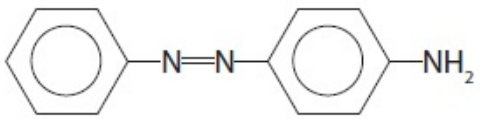


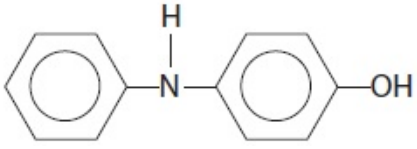
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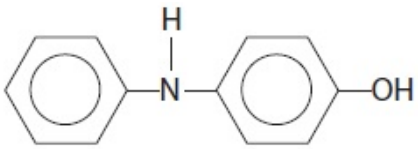


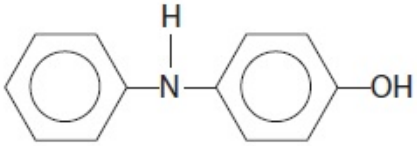
B



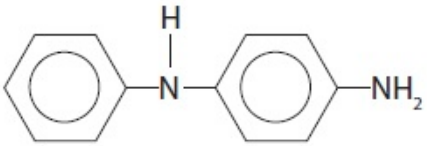


C





D

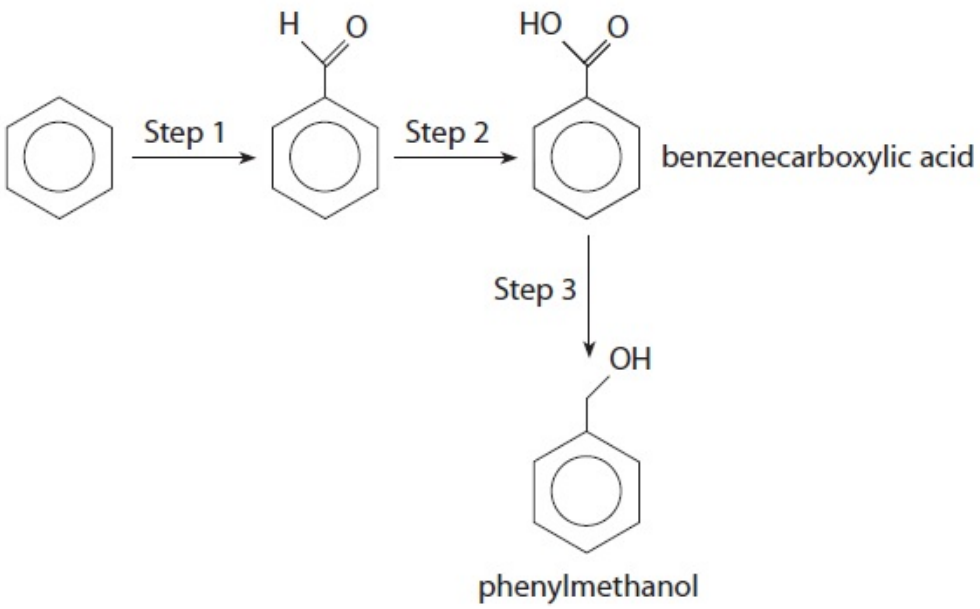


(Total for question = 3 marks)

Q16.

Benzenecarboxylic acid (benzoic acid) and phenylmethanol (benzyl alcohol) are compounds which occur naturally and have a wide range of uses. For example, benzenecarboxylic acid is used as a food preservative and phenylmethanol is used as a solvent.

A laboratory sequence for the preparation of these two compounds is shown below.



(a) In the first step of the synthesis, benzene reacts with hydrogen chloride and carbon monoxide in the presence of aluminium chloride in an electrophilic substitution called the Gattermann-Koch reaction. The hydrogen chloride and carbon monoxide together behave as if they form the unstable species methanoyl chloride (HCOCl).

(i) Explain why benzene undergoes substitution rather than addition reactions. A detailed description of the bonding in benzene is **not** required.

(2)

.....

.....

.....

.....

(ii) Give the mechanism for step 1, including the formation of the electrophile.

(4)

(iii) Identify the reagents and essential conditions used in the remaining steps of the sequence. You may assume that the correct reaction temperatures are being used.

(4)

Step 2

Step 3

*(b) Phenol reacts faster than phenylmethanol in electrophilic substitution reactions. Suggest why this is so.

(4)

.....

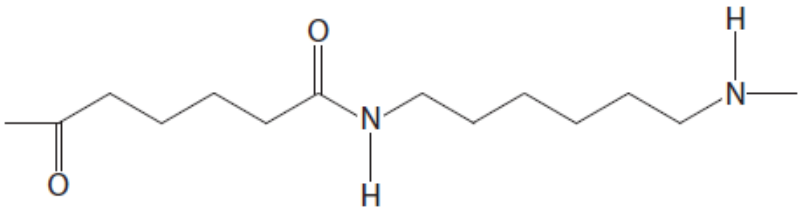
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(Total for question = 14 marks)

Q17.

This question is about amines.

A section of a polyamide is shown.



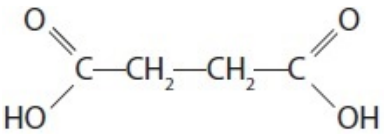
Identify, by name or formula, the amine monomer that reacts to form this polyamide.

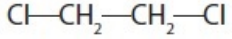
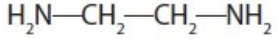
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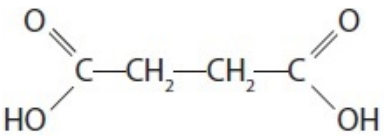
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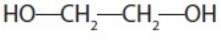
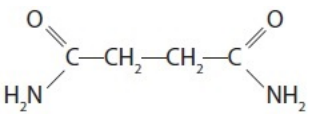
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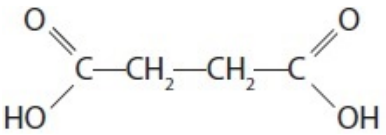
Q18. Which of the following pairs of compounds could form a polyamide?

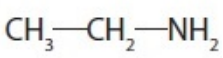
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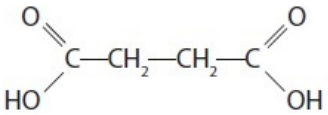
A  and 

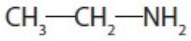
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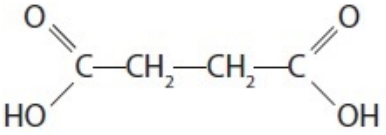
B  and 

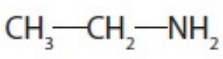


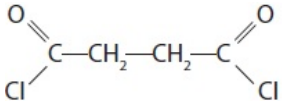
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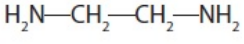
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and 

D 

and 

(Total for Question = 1 mark)

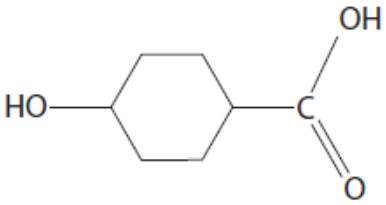
Q19.

* This question is about polymers.

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



cyclohexene



4-hydroxycyclohexanecarboxylic acid

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

(6)

(Total for question = 6 marks)

Q20.

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

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

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

relevant lone pairs.

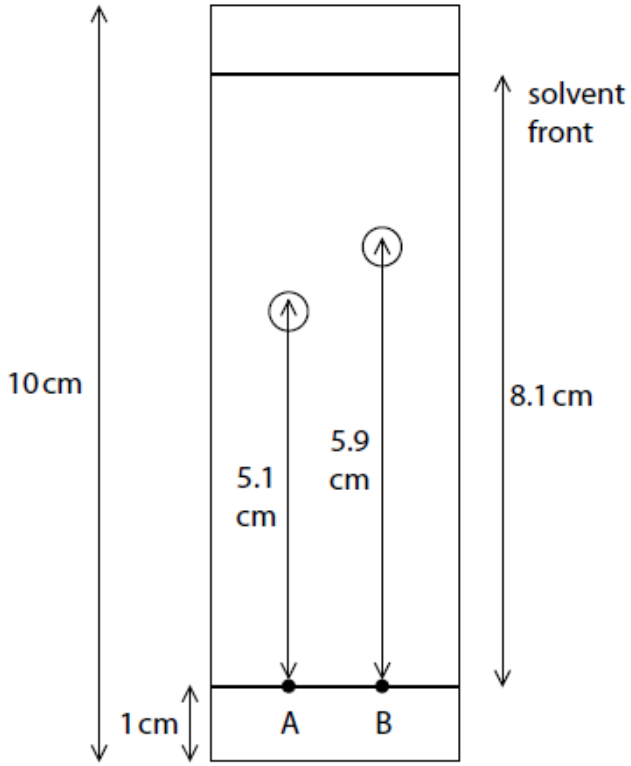
(3)

(Total for question = 3 marks)

Q21.

This question is about the properties of amino acids and other organic compounds.

A chromatogram of two amino acids, **A** and **B**, is shown.



Amino acid **B** has the structure $H_2NCH(CH_2CH(CH_3)_2)COOH$.

Predict the pH of the solution formed when it dissolves in water and justify your answer.

(2)

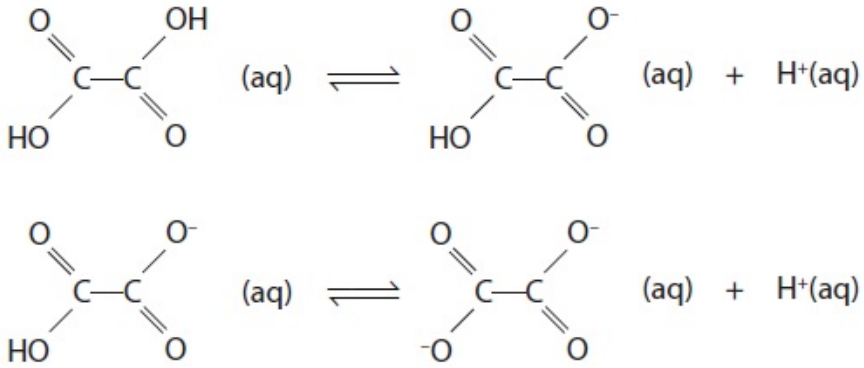
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Q22. Ethanedioic acid (also known as oxalic acid) is a dicarboxylic acid. Like sulfuric acid, it has two replaceable hydrogen atoms so it dissociates in two stages which are shown below. Acids like these are called 'dibasic'.



As is always the case with dibasic acids, the first dissociation occurs to a far greater extent than the second. Ethanedioic acid is a carboxylic acid but, because there are two carboxyl groups, it is a much stronger acid than ethanoic acid.

Ethanedioic acid is toxic, mainly due to the precipitation of calcium ethanedioate in the kidneys. As it occurs in many plants, the toxicity of ethanedioic acid has caused a number of deaths notably during the First World War when people in England used rhubarb leaves, which contain significant concentrations of the compound, as a vegetable substitute. As it is a reducing agent, the concentration of ethanedioic acid is usually determined by titration with a solution of potassium manganate(VII) of known concentration.

The ethanedioate ion, which is formed when ethanedioic acid dissociates fully, is a bidentate ligand. The ethanedioate ion together with 1,2-diaminocyclohexane, another bidentate ligand, forms a complex with platinum(II) called oxaliplatin which has the same geometry as cisplatin. Oxaliplatin is an anti-cancer drug, which has been used to treat cancers that have become resistant to cisplatin.

Ethanedioic acid has numerous uses, from cleaning and rust removal to the purification of metals. Although it can be prepared from ethene in a two stage process, it is usually manufactured by the oxidation of carbohydrates or glucose using nitric acid, or air, in the presence of vanadium(V) oxide.

(a) (i) Suggest why the presence of the second carboxylic acid group increases the extent of the **first** dissociation of ethanedioic acid compared with the dissociation of ethanoic acid.

(2)

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(ii) Explain, by referring to the equilibria in the passage, why the second dissociation of a dibasic acid occurs to a lesser extent than the first.

(1)

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(b) In an experiment to determine the proportion of ethanedioic acid in rhubarb leaves, 250 g of leaves was crushed and boiled in a solution of sodium carbonate. The resulting mixture was filtered and the filtrate transferred, along with washings from the mixture, to a 250 cm^3 volumetric flask. The solution was acidified with sulfuric acid, made up to the mark and mixed thoroughly. 25.0 cm^3 portions of the solution were pipetted into a conical flask, about 25 cm^3 of sulfuric acid added and the mixture titrated against a solution of potassium manganate(VII) of concentration 0.0200 mol dm^{-3}. The mean titre was 28.55 cm^3. The relevant ionic half equations for the reaction are

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

$$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$$

(i) State the colour change that occurs at the end-point of the titration.

(1)

.....

*(ii) Calculate the percentage by mass of ethanedioic acid in rhubarb leaves.

(5)

(c) (i) Explain the term 'bidentate'.

(1)

.....

.....

(ii) Draw a diagram of the oxaliplatin(II) complex, showing clearly the geometry and charge of the complex and how the ligands are attached to the central ion.

(3)

(d) (i) Suggest a two step **laboratory** synthesis of ethanedioic acid from ethene. Indicate the intermediate compound formed and the reagents required.

(3)

(ii) Suggest why it is preferable from an environmental perspective that ethanedioic acid is manufactured from carbohydrates and glucose rather than from ethene.

(1)

.....

.....

(iii) A sample of ethanedioic acid, manufactured from glucose, was contaminated with a small amount of propanoic acid.

High resolution nmr may be used to distinguish propanoic acid from ethanedioic acid.

Describe the high resolution nmr spectra of both propanoic acid and ethanedioic acid. Do **not** include chemical shift data in your answer.

(4)

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(Total for Question = 21 marks)

Q23. Which of the following is true for **all** amino acids?

All amino acids

- ☒ **A** exist as optical isomers.
- ☒ **B** are neutral in solution.
- ☒ **C** are essential to life.
- ☒ **D** are crystalline solids at room temperature.

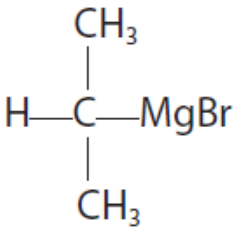
(Total for Question = 1 mark)

Q24.

Grignard reagents are used in organic synthesis as a way of increasing the length of the carbon

chain in a molecule.

(a) The structure of the Grignard reagent formed by the reaction between 2-bromopropane and magnesium is



On the diagram, draw the permanent dipole involving the central carbon atom.

(1)

(b) The Grignard reagent in part (a) reacts with propanal.

(i) Draw the **fully displayed** formula of the final organic product of this reaction.

(1)

(ii) Name the organic product in (b)(i).

(1)

.....

(c) Identify, by using ticks, **two** boxes in the table to select appropriate terms that describe a Grignard reagent.

(2)

acid	
electrophile	
nucleophile	
oxidising agent	
reducing agent	

(d) The solvent used for Grignard reagents has to be completely **dry**.

By considering the dipole on the O—H bonds in water, predict the identity of the organic product that forms if water is added to the Grignard compound in part (a).

(1)

.....

(Total for question = 6 marks)

Q25.

Solid benzoic acid is usually purified by recrystallisation from hot water.
The method used is:

1 The impure solid is dissolved in the minimum volume of hot water.

2 The solution is quickly filtered.

3 The solution is allowed to cool and crystallise.

4 The crystals are filtered from the remaining solution.

5 The crystals are washed with a little cold water.

6 The crystals are left to dry.

(a) State how steps **2**, **4** and **5** remove impurities from the benzoic acid.

(3)

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(b) Describe how impurities affect the melting temperature of an impure solid.

(2)

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Q26.

This question is about amines.

A student wrote a statement about the mechanism of the reaction between a primary chloroalkane and an amine.

> The amine acts as a nucleophile due to its unpaired electron. It attacks the slightly positive carbon in the chloroalkane, forming an intermediate. The carbon is slightly positive as it is attached to an electropositive chlorine atom. The intermediate then loses a proton and a chloride ion, forming the product, an N-substituted amide.

Identify and correct **two** of the errors in the statement.

(2)

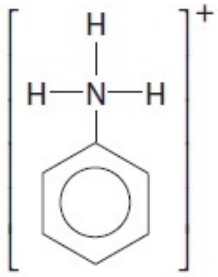
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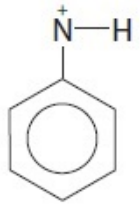
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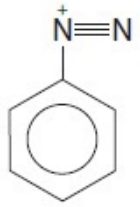
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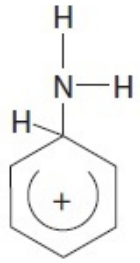
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Q27. When dilute nitric(V) acid, HNO_3, reacts with phenylamine, the ion formed is

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

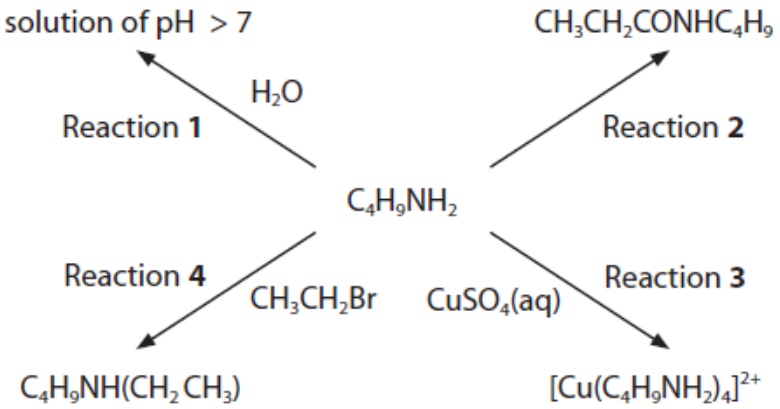
(Total for Question = 1 mark)

Q28.

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

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

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



What is seen when excess butylamine is used in Reaction **3**?

(1)

☒ **A** blue solution

☒ **B** blue precipitate

☒ **C** yellow solution

☒ **D** yellow precipitate

(Total for question = 1 mark)

Q29.

Benzene reacts with a nitrating mixture of concentrated nitric and sulfuric acids.
Which species is **least** likely to be present in the nitrating mixture?

☒ **A** NO_3^-

☒ **B** H_3O^+

☒ **C** HSO_4^-

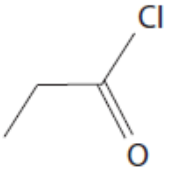
☒ **D** NO_2^+

(Total for question = 1 mark)

Q30.

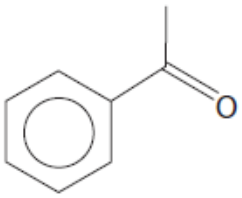
Benzene reacts with propanoyl chloride in the presence of a suitable catalyst.

The skeletal formula of propanoyl chloride is

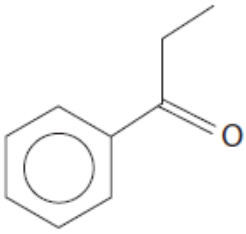


What is the organic product of this reaction?

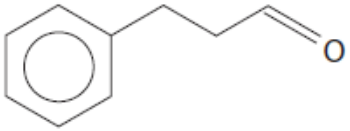
☒ **A**



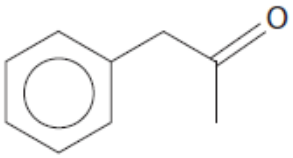
☒ **B**



☒ **C**

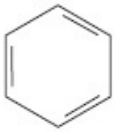
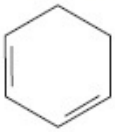


☒ **D**



(Total for question = 1 mark)

Q31. Bromine reacts with benzene on heating in the presence of a catalyst and with cyclohexa-1,3-diene in the cold. The types of reaction involved are

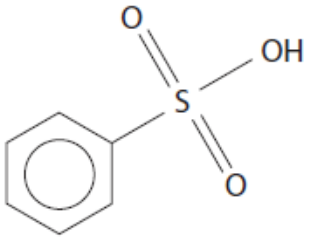
	bromine with benzene 	bromine with cyclohexa-1,3-diene 
☐ **A**	addition	addition
☐ **B**	addition	substitution
☐ **C**	substitution	addition
☐ **D**	substitution	substitution

(Total for Question = 1 mark)

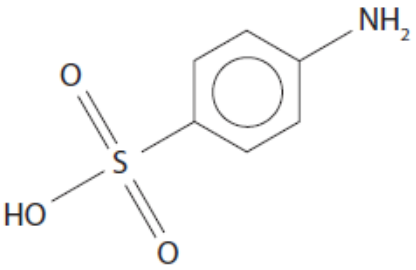
Q32.

Excess dilute sulfuric acid is added to phenylamine. What is the product of the reaction?

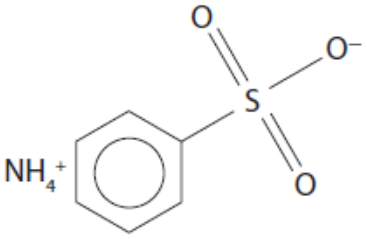
☒ **A**



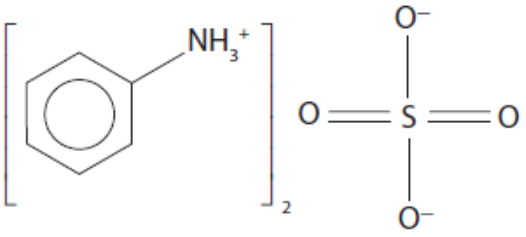
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q33.

Tests are carried out on aqueous solutions of two salts, **X** and **Y**.

Y contains one cation and one anion.

The observations for each test are recorded in the table.

(i) Complete the table by writing the names or formulae of the species.

(2)

Test	Observation	Inference
Test 3 Add dilute aqueous ammonia to an aqueous solution of **Y** until it is present in excess	A pale blue precipitate forms The precipitate dissolves in excess ammonia to form a deep blue solution	The cation in **Y** is .....
Test 4 To an aqueous solution of **Y**, add dilute nitric acid followed by aqueous silver nitrate	A white precipitate forms	The anion in **Y** is .....

(ii) Give the formula of the complex ion present in the deep blue solution at the end of **Test 3**.

(1)

.....

(iii) Give a reagent that could be added to the mixture at the end of **Test 4** to confirm the identity of the anion in **Y**.

Include the observation when this reagent is added.

(2)

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(Total for question = 5 marks)

Q34. (a) The following data were obtained from experiments on solutions of aqueous amines of the same concentration.

Amine	Formula	pH of solution
Butylamine	$CH_3CH_2CH_2CH_2NH_2$	11.9
Dibutylamine	$(CH_3CH_2CH_2CH_2)_2NH$	12.1
Phenylamine (aniline)	$C_6H_5NH_2$	8.8

(i) Identify the feature of the amine molecules that causes the solutions to be alkaline.

(1)

.....

.....

(ii) Write the equation for the reaction that occurs when butylamine is dissolved in water. State symbols are not required.

(1)

*(iii) Suggest why the dibutylamine solution is more alkaline than the butylamine solution.

(2)

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*(iv) Suggest why the phenylamine solution is much less alkaline than the butylamine solution.

(2)

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(b) When butylamine is added to an aqueous solution of copper(II) sulfate, initially a pale blue precipitate is formed. When excess butylamine is added, the precipitate dissolves to form a deep blue solution.

Complete the equations below. State symbols are not required.

(4)

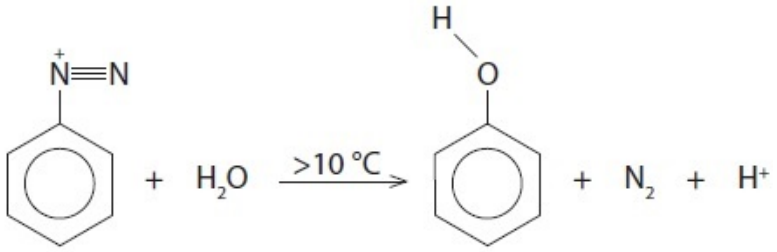
I Formation of the pale blue precipitate

$Cu(H_2O)_6^{2+} + 2C_4H_9NH_2 \rightarrow$

II The overall equation for the formation of the deep blue solution

$Cu(H_2O)_6^{2+} + 4C_4H_9NH_2 \rightarrow$

*(c) When phenylamine is treated with a mixture of sodium nitrite, $NaNO_2$, and hydrochloric acid at about 5 °C, the resulting solution contains the benzenediazonium ion. If the temperature of this solution is allowed to rise above 10 °C, the benzenediazonium ion reacts to form phenol:



By considering the role of the water molecule in this reaction, state the type and mechanism occurring and explain why it is unusual in benzene chemistry.

(2)

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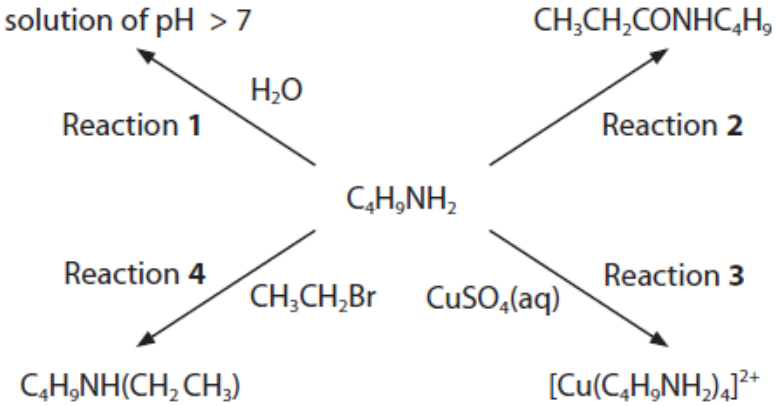
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(Total for Question = 12 marks)

Q35.

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

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



(i) Write the equation for Reaction **1** to show why the pH of the solution is greater than 7. State symbols are not required.

(1)

(ii) Explain why phenylamine is a weaker base than butylamine.

(3)

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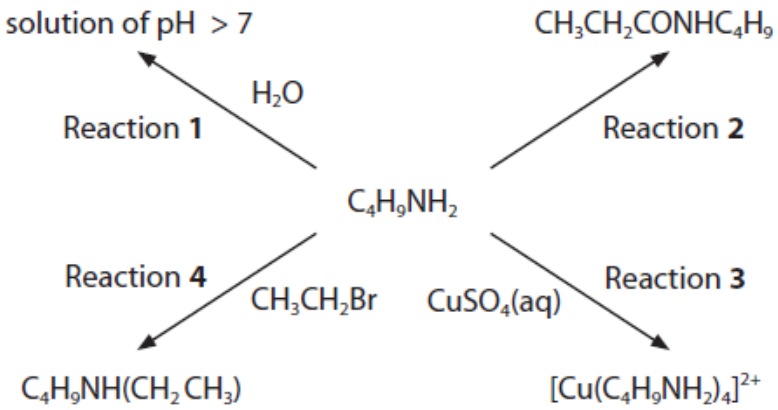
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(Total for question = 4 marks)

Q36.

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

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



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

(2)

Name.....

Structural formula.....

(Total for question = 2 marks)

Q37. A scientist investigated the typical behaviour of primary amines.

(a) Amines such as butylamine, $CH_3CH_2CH_2CH_2NH_2$, and phenylamine, $C_6H_5NH_2$, both behave as bases.

(i) Which feature of an amine molecule allows it to act as a base?

(1)

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.....

(ii) The scientist reacted butylamine with two different acids.

Give the **formulae** of the salts that are formed when butylamine reacts with

(2)

sulfuric acid,
H_2SO_4
.....

ethanoic acid,
CH_3COOH
.....

(b) Phenylamine, $C_6H_5NH_2$, is formed by the reduction of nitrobenzene, $C_6H_5NO_2$.

Give the reagents that are used for this reduction.

(2)

.....

.....

(c) Phenylamine was reacted with a mixture of sodium nitrite, $NaNO_2$, and hydrochloric acid at a temperature between 0 °C and 5 °C. A diazonium ion was formed. In a second step, the scientist reacted the diazonium ion with phenol, under suitable conditions. A precipitate of 4-hydroxyazobenzene (4-hydroxyphenylazobenzene) was formed.

(i) Draw the structure of the diazonium ion, clearly displaying the functional group present in the ion.

(1)

(ii) Draw the structural formula of 4-hydroxyazobenzene.

(1)

(iii) State a condition, other than a suitable temperature, required for the reaction of the diazonium ion with phenol and give a use for 4-hydroxyazobenzene.

(2)

Condition required:

.....

Use for 4-hydroxyazobenzene:

.....

(d) The scientist repeated the first step in experiment (c), but the temperature was allowed to rise above 10°C. Under these conditions, the diazonium ion reacted with water to produce phenol. An unreactive gas, of molar mass 28.0 g mol^{-1}, was also formed along with one other product.

Use this information to write the equation for the reaction of the diazonium ion with water.

(2)

(e) The impure sample of 4-hydroxyazobenzene formed in part (c) may be purified by recrystallization. During this process

- the solid is dissolved in the minimum volume of hot solvent
- the mixture is then filtered whilst still hot
- the filtrate is cooled in an ice bath to produce crystals of 4-hydroxyazobenzene
- the crystals are removed by filtration and dried.

(i) Why is the "minimum volume of hot solvent" used?

(1)

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(ii) The impure 4-hydroxyazobenzene may contain both insoluble and soluble impurities. Describe how

(2)

I. insoluble impurities are removed during recrystallization

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II. soluble impurities are removed during recrystallization

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(iii) How would you check the purity of 4-hydroxyazobenzene after recrystallization, other than by using spectroscopy?

(1)

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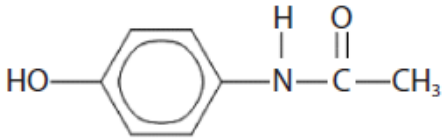
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(Total for Question = 15 marks)

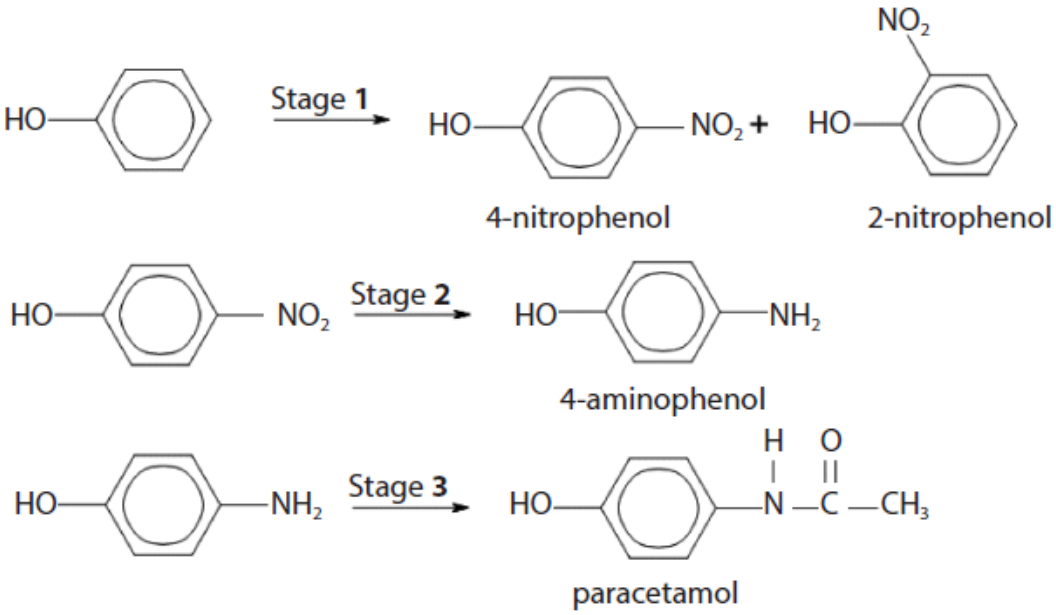
Q38.

This question is about the preparation and analysis of paracetamol.



paracetamol

Paracetamol may be prepared from phenol in three stages.



In Stage **1**, phenol is nitrated using dilute nitric acid.

The nitration of benzene requires concentrated nitric acid at 55°C with a catalyst of concentrated sulfuric acid.
Both these reactions are electrophilic substitution.

(i) Explain why phenol can be nitrated using milder conditions than benzene.

(2)

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(ii) A mixture of 2-nitrophenol and 4-nitrophenol is produced in Stage **1**.
They are separated by steam distillation.

The boiling temperature of 2-nitrophenol is 215°C and that of 4-nitrophenol is 279°C.

Explain, in terms of intermolecular forces, why 4-nitrophenol has a higher boiling temperature than 2-nitrophenol.
You may include a diagram in your answer.

(2)

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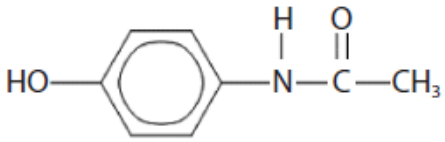
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(Total for question = 4 marks)

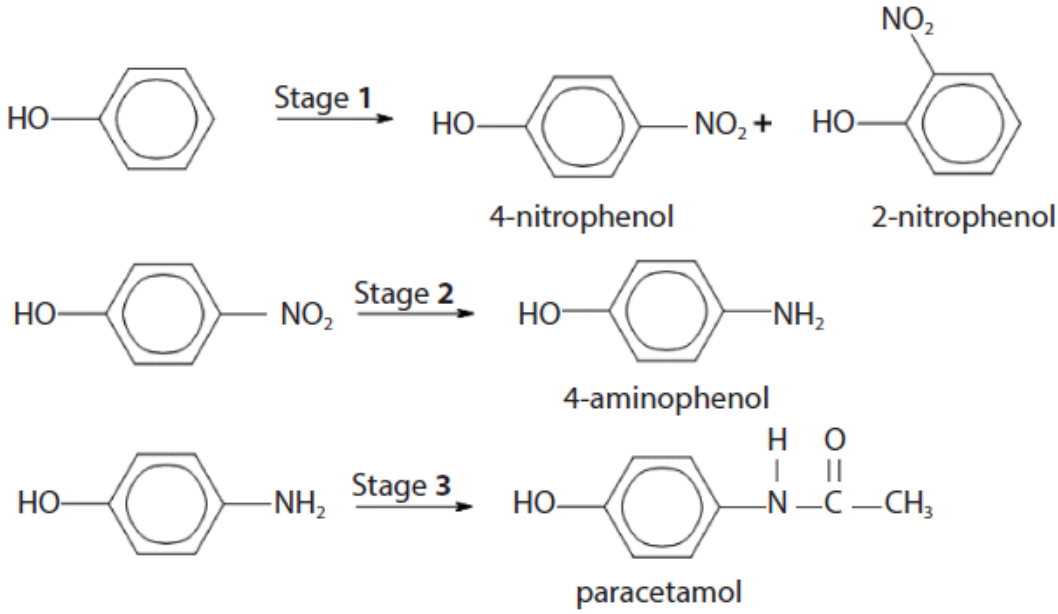
Q39.

This question is about the preparation and analysis of paracetamol.



paracetamol

Paracetamol may be prepared from phenol in three stages.



State the **type** of reagent needed to convert 4-nitrophenol into 4-aminophenol in Stage **2**.

(1)

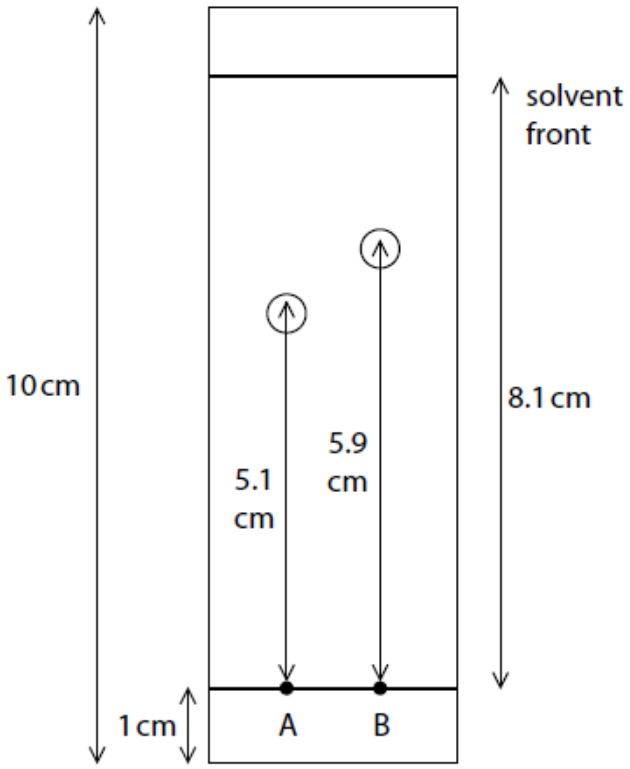
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(Total for question = 1 mark)

Q40.

This question is about the properties of amino acids and other organic compounds.

A chromatogram of two amino acids, **A** and **B**, is shown.



The R_f value of amino acid A is

(1)

- ☒ **A** 0.51
- ☒ **B** 0.56
- ☒ **C** 0.63
- ☒ **D** 0.67

Q41. Which of the following is **not** planar?



A





B CCl_4



C BF_3



D $[Pt(NH_3)_2Cl_2]$

(Total for Question = 1 mark)

Q42. Methylamine, CH_3NH_2, is **very** soluble in water. This is because it

☒ **A** forms hydrogen bonds with water.

☒ **B** forms London forces with water.

☒ **C** exists mainly as ions in aqueous solution.

☒ **D** exists as a zwitterion.

(Total for Question = 1 mark)

Q43.

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

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

The steam distillate is washed with saturated sodium chloride solution and the oil separated and dried.

(i) Draw a diagram of the apparatus you would use to separate the oil, labelling the oil.

[Densities: cinnamon oil 1.050 g cm^{-3}; sodium chloride solution 1.122 g cm^{-3}]

(2)

(ii) Give the name of a chemical that could be used to dry the oil.

(1)

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(iii) State the change in appearance of the oil when it is being dried.

(1)

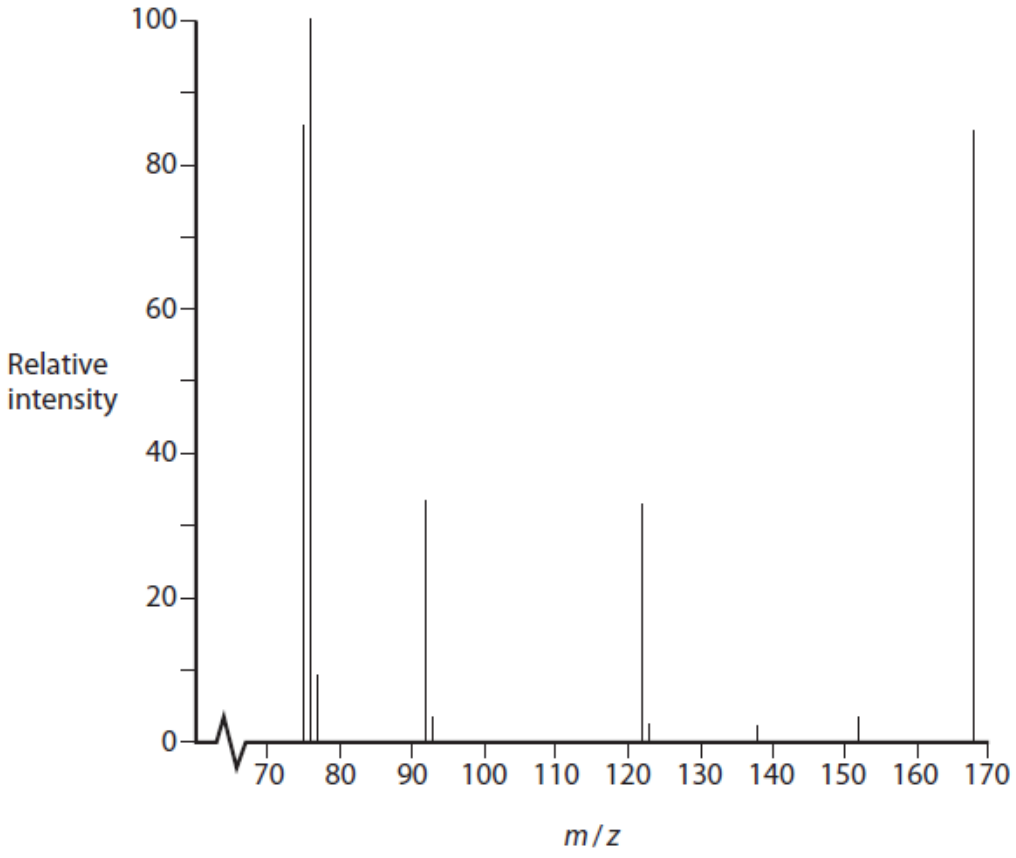
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Q44.

Organic compound **D** contains the elements carbon, hydrogen, oxygen and nitrogen only.

Part of the mass spectrum of **D** is shown.



Compound **D** contains a benzene ring.

(i) Give the molecular formula of the species that causes the peak at $m / z = 76$ in the mass spectrum of **D**.

.....

(1)

(ii) Draw the structures of the **three** possible isomers of **D** containing a benzene ring.

(2)

(iii) The ^{13}C NMR spectrum of compound **D** has four peaks.

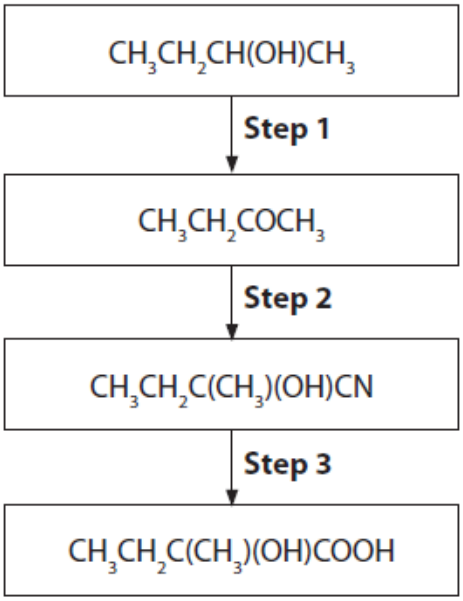
Identify the structure of **D**. Justify your answer by labelling the different carbon environments in **all** the structures drawn in (ii).

(3)

(Total for question = 6 marks)

Q45.

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



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

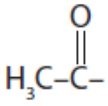
(2)

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

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

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

(4)

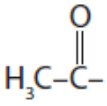
Carbonyl group

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 group

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

Give the mechanism for this reaction.

(3)

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

(3)

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

(1)

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

(1)

.....

.....

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

Give the chemical shift you would expect for this peak.

(1)

.....

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

(1)

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

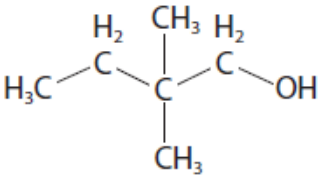
Draw a **displayed** formula for this polymer, showing two repeating units.

(2)

(Total for question = 18 marks)

Q46.

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



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

(6)

(Total for question = 6 marks)

Q47.

Benzene

Benzene was first discovered by Michael Faraday in London in 1825. He identified it by distilling a liquid obtained from condensing a gas produced by heating whale oil.

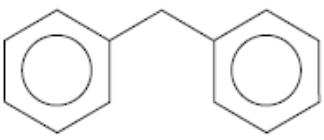
In 1834, Mitscherlich discovered the same liquid could be obtained by heating benzoic acid with lime.

Benzene is now produced from petroleum. Petroleum is fractionally distilled and benzene is obtained from the hexane in the naphtha fraction.

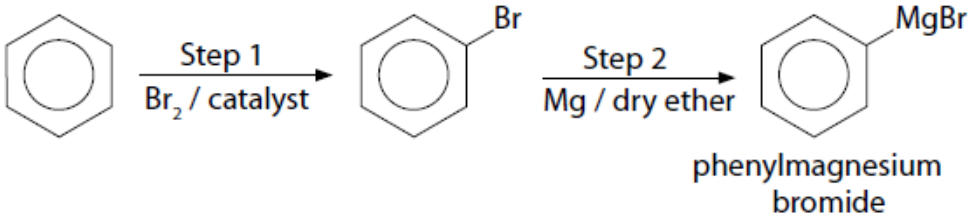
Hexane is heated to about 770 K. It then passes to a reactor where it reacts to form cyclohexane and hydrogen. The cyclohexane is then dehydrogenated to form benzene. Other aromatic products like methylbenzene and dimethylbenzenes are also produced. The aromatic products are separated by further distillation.

Benzene is the starting compound for a large number of useful chemicals and materials. For example it is used to make the polymer, poly(phenylethene).

Diphenylmethane is used to provide the geranium fragrance in soap.



It can be synthesised in five steps from benzene. The first two steps in the process are



(i) Name the catalyst in Step 1.

(1)

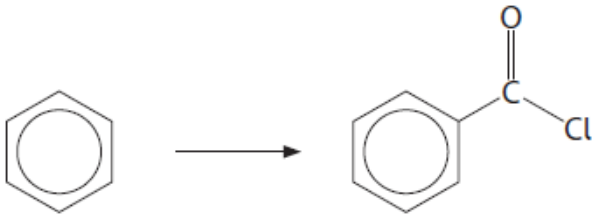
(ii) Write a three step synthesis to convert phenylmagnesium bromide to diphenylmethane, including reagents used in each step.

(6)

Q48.

This question is about the synthesis of organic compounds.

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



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

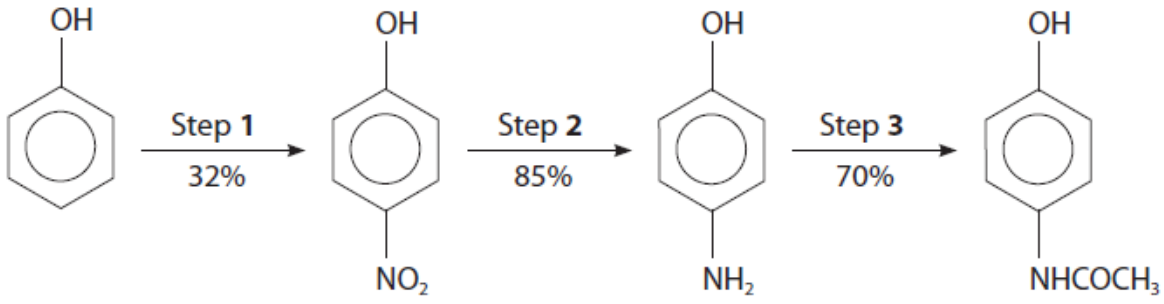
(7)

(Total for question = 7 marks)

Q49.

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

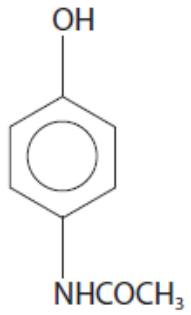
The painkiller paracetamol can be synthesised from phenol in three steps.
The percentage yield for each step is shown.



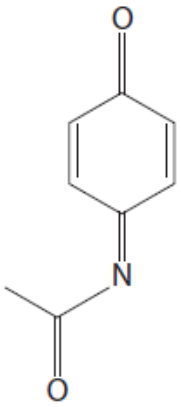
phenol

paracetamol

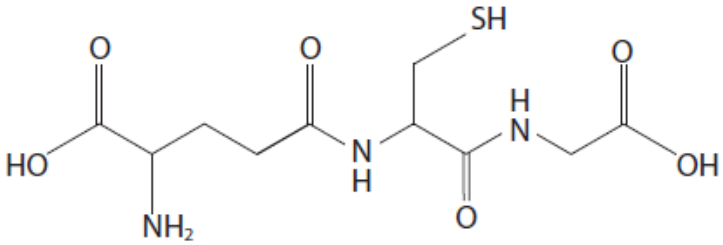
When metabolised in the body, paracetamol forms a toxic compound **Z**.
This is then removed in the liver by a reaction with the tripeptide glutathione.



paracetamol



compound **Z**



glutathione

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

(1)

☒ **A** addition

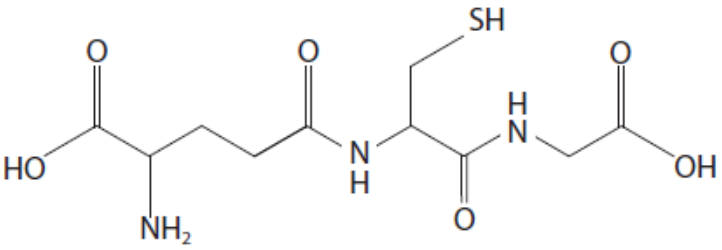
☒ **B** hydrolysis

☒ **C** oxidation

☒ **D** reduction

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

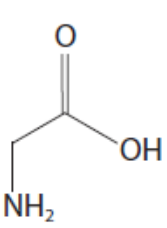
(1)



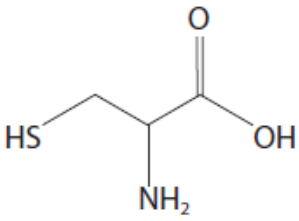
(iii) Glutathione is formed from glycine and two other amino acids.

Which two amino acids combine with glycine to form glutathione?

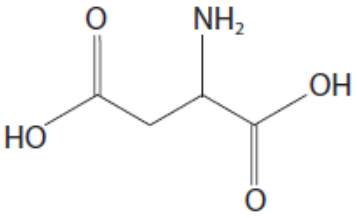
(1)



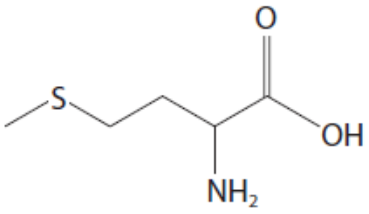
glycine



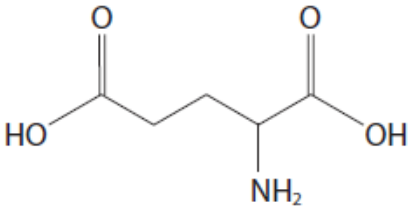
cysteine



aspartic acid



methionine



glutamic acid

☒ **A** aspartic acid and cysteine

☒ **B** glutamic acid and cysteine

☒ **C** glutamic acid and methionine

☒ **D** aspartic acid and methionine

(Total for question = 4 marks)

Q50.

Propanoic acid can be synthesised from propene, a by-product of the petrochemical industry.

(a) Complete the equation to show the formation of propene and one other hydrocarbon.

$C_{10}H_{22} \rightarrow C_3H_6 +$ .....

(1)

(b) Propanoic acid can be synthesised from propene in 3 steps. A student proposed the following synthesis:

Step 1: propene → 1-bromopropane

Step 2: 1-bromopropane → **X**

Step 3: **X** → propanoic acid

(i) Identify **X** and give the conditions needed to carry out Step 2 and Step 3 in this synthesis.

(4)

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(ii) Explain, by considering the mechanism of the reaction, why the student's choice of reaction for Step 1 will lead to a low overall yield.

(2)

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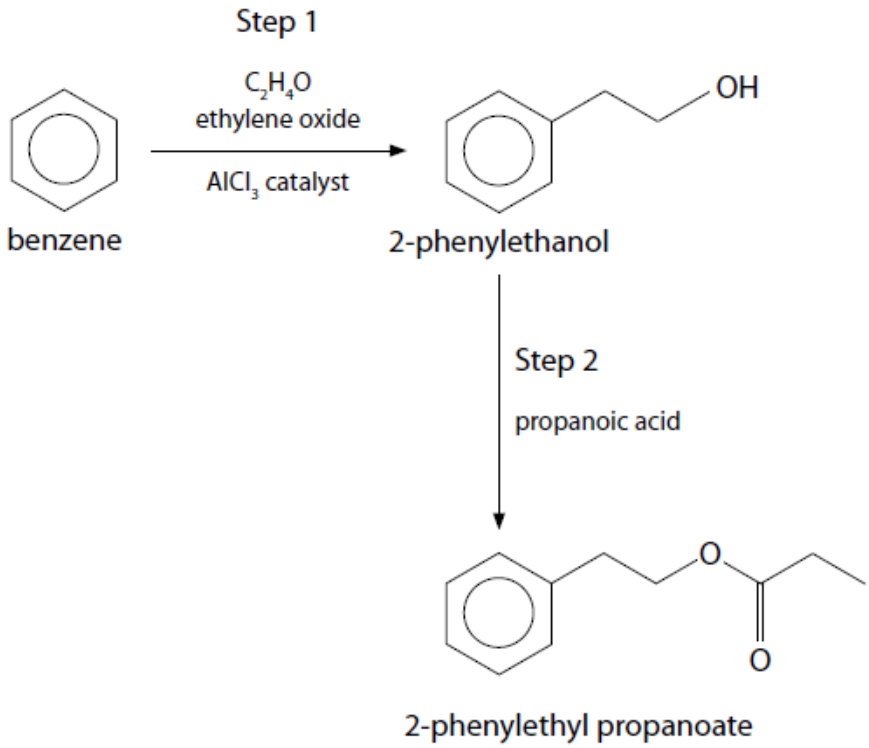
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Q51.

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

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



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

What is the mechanism in this step?

(1)

☒ **A** electrophilic substitution

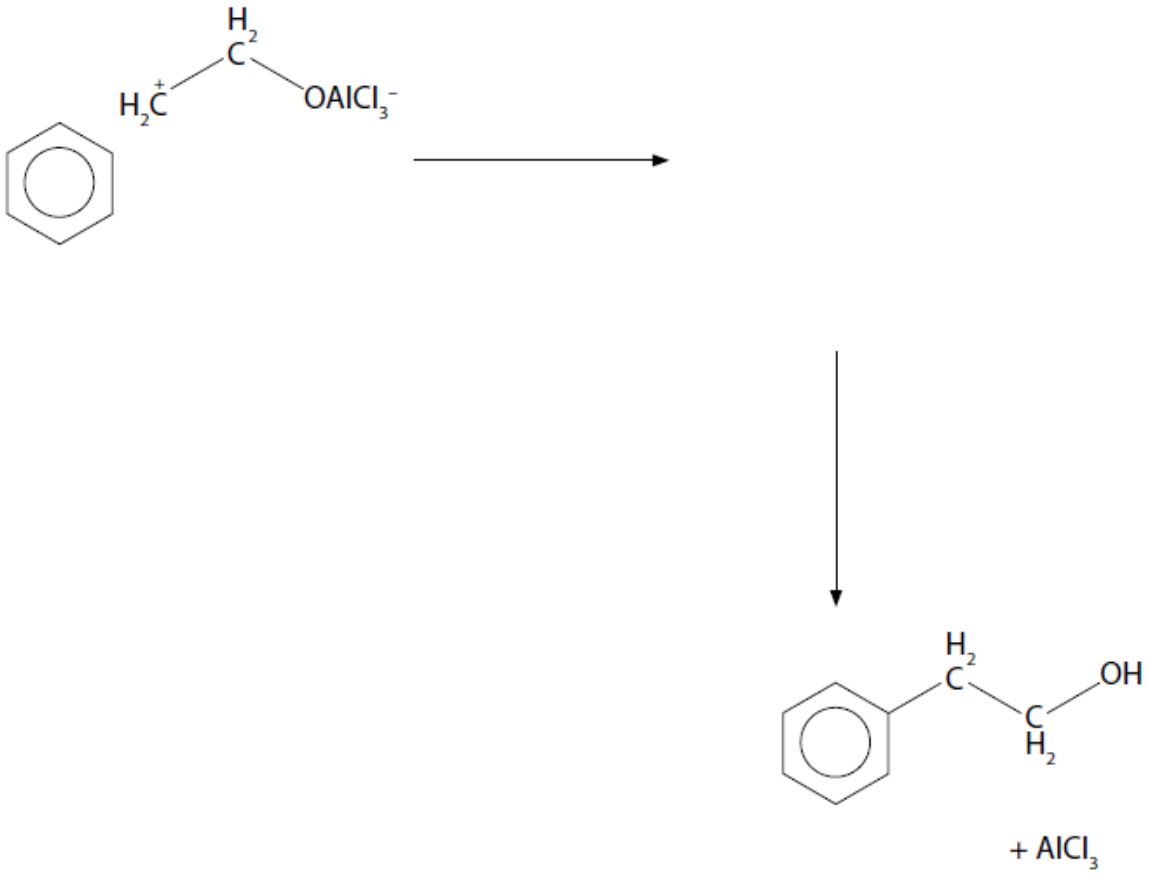
☒ **B** nucleophilic substitution

☒ **C** electrophilic addition

☒ **D** nucleophilic addition

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

(4)



(iii) In the synthetic route, what type of reaction is Step 2?

(1)

- ☒ **A** hydrolysis
- ☒ **B** esterification
- ☒ **C** neutralisation
- ☒ **D** hydrogenation

(iv) Name a suitable catalyst for Step 2.

(1)

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.....

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Q52.

This question is about amines.

Compare and contrast the basicity of phenylamine and butylamine.

(3)

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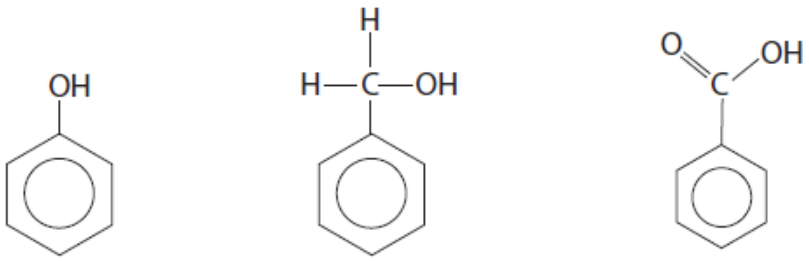
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(Total for question = 3 marks)

Q53.

This is a question about the analysis of three aromatic substances with —OH groups.



phenol phenylmethanol benzoic acid

Spectroscopy is an effective means of distinguishing between molecules.

(i) Compare and contrast the infrared spectra of phenol, phenylmethanol and benzoic acid. Include relevant bonds and their wavenumber ranges using the Data Booklet.

(5)

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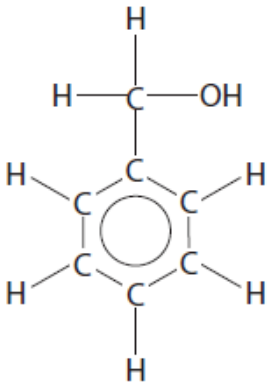
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(ii) Predict the number of peaks present, and their chemical shifts, in the ^{13}C nuclear magnetic resonance (NMR) spectrum of

phenylmethanol.

Use the information in the Data Booklet to help you.

(3)



phenylmethanol

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(iii) Give the formula of a fragment ion, with its *m*/*z* value, that you would expect to be present in the mass spectrum of

benzoic acid but **not** in the mass spectrum of phenol or the mass spectrum of

phenylmethanol.

(2)

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(Total for question = 10 marks)

Q54.

Propanoic acid can be synthesised from propene, a by-product of the petrochemical industry.

Propene is used in the manufacture of polymers.

(i) Write an equation to show the formation of poly(propene) from propene.

(2)

(ii) Describe how the chemical reaction to form the polymer nylon differs from the chemical reaction to form poly(propene).

(2)

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(iii) Give **two** ways in which chemists contribute to a more sustainable use of such materials as poly(propene) and nylon.

(2)

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Q55.

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

The following steps were carried out.

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

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

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

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

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

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

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

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

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

Explain why the addition of hydrochloric acid in Step **6** results in the precipitation of benzoic acid.

(2)

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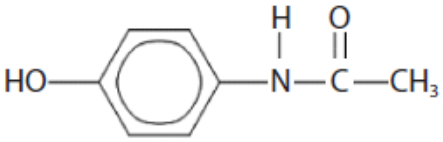
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(Total for question = 2 marks)

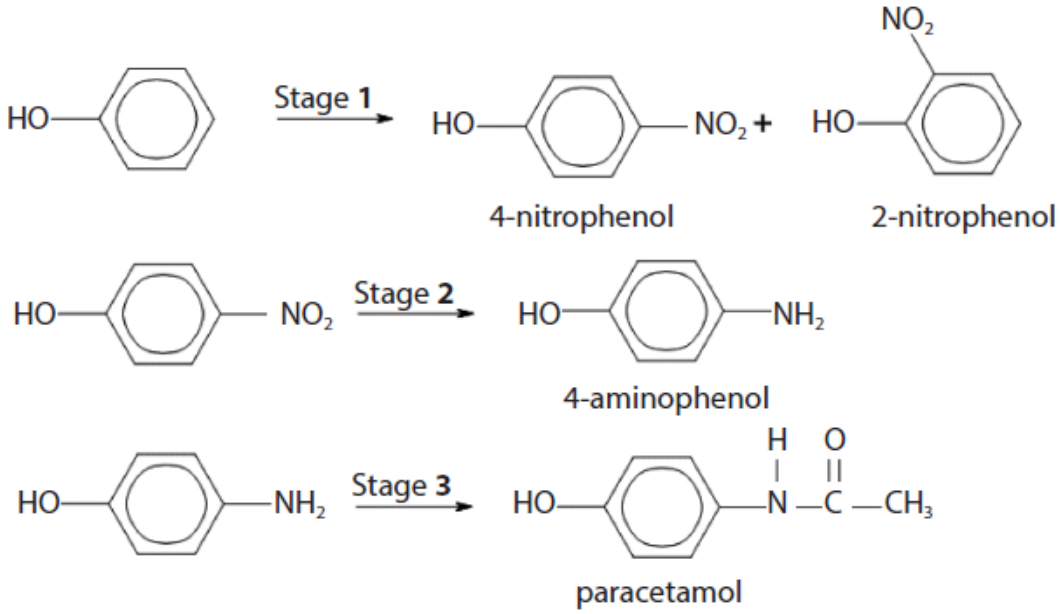
Q56.

This question is about the preparation and analysis of paracetamol.



paracetamol

Paracetamol may be prepared from phenol in three stages.



The outline procedure for Stage **3** is:

- place 1.0 g of 4-aminophenol in a conical flask. Add 9 cm^3 of distilled water and stir the mixture
- add 1 cm^3 of ethanoic anhydride to the flask and shake the mixture until a precipitate of impure paracetamol forms
- remove the paracetamol by filtration under reduced pressure
- recrystallise the paracetamol using water as the solvent
- determine the melting temperature of the pure, dry paracetamol.

(i) Draw a labelled diagram of the apparatus used for filtration under reduced pressure.

(3)

(ii) Describe the recrystallisation process to obtain a pure, dry sample of paracetamol.

(5)

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(iii) The melting temperature of pure paracetamol is 170°C.

Describe what happens to the melting temperature if the paracetamol is not pure.

(2)

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(Total for question = 10 marks)

Q57.

This question is about amines.

Write the equation for the reaction between propanoyl chloride and pentylamine.
Include the name of the amide formed.

State symbols are not required.

(2)

Name of amide

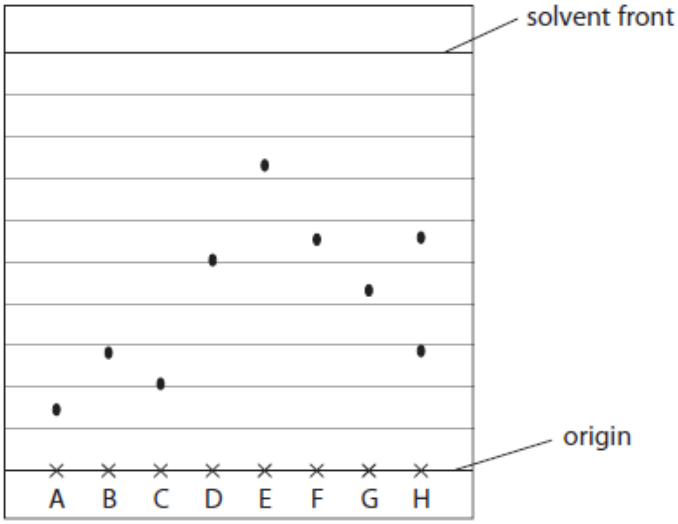
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(Total for question = 2 marks)

Q58.

Chromatography is a technique used to separate the components of a mixture.

A sample of a tripeptide was hydrolysed and then placed on a thin layer chromatography (TLC) plate. Samples of possible amino acids present were also placed on the TLC plate for reference. A simplified diagram of the developed TLC plate is shown.



A – Lysine	B – Serine	C – Histidine	D – Tyrosine
E – Isoleucine	F – Methionine	G – Proline	H – Hydrolysed tripeptide

(i) Calculate the R_f value for the amino acid lysine.

Give your answer to an appropriate number of significant figures.

(1)

(ii) Identify by **name** the two amino acids present in the tripeptide, giving a reason for the lack of a third spot.

(3)

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(iii) Give **two** reasons why different amino acids have different R_f values.

(2)

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(iv) In chromatography, a 'locating' reagent is often used when the components in a mixture are colourless.

Which reagent is used to locate the amino acid spots?

(1)

☒ **A** iodine

☒ **B** methyl orange

☒ **C** ninhydrin

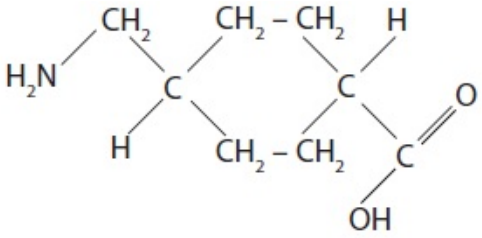
☒ **D** phenolphthalein

(Total for question = 7 marks)

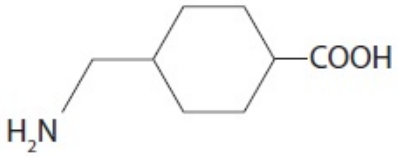
Q59.

Tranexamic acid

Tranexamic acid is an amino acid. It is a white crystalline solid which melts at 300 ºC. It is used to reduce bleeding during surgery and dental procedures and is especially useful where patients suffer from deficiencies in blood-clotting factors. The structure of tranexamic acid can be drawn as shown below.



or



As the name suggests, tranexamic acid is the *trans* form of a compound that forms geometric (or *cis-trans* or *E-Z*) isomers.

(a)

(i) Explain why some molecules which contain a C═C double bond show geometric isomerism.

(2)

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(ii) Suggest how tranexamic acid can form geometric isomers although it does not have a C═C double bond.

(1)

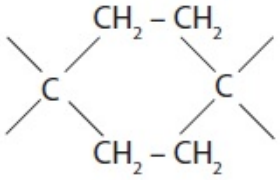
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(iii) Complete the diagram to show the structure of the cis isomer.

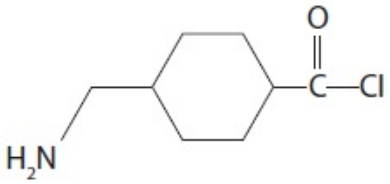
(1)



(iv) Explain why tranexamic acid melts at 300 ºC while the alkane, undecane ($C_{11}H_{24}$) which has almost the same number of electrons, melts at −26 ºC. A detailed description of the forces involved is **not** required.

(3)

(b) The diagram below shows a compound, **K**, which is a derivative of tranexamic acid.



(i) Identify by name or formula a compound that might react with tranexamic acid to form **K**.

(1)

(ii) Under suitable conditions, molecules of **K** react together forming a polymer, **L**. Draw the structure of **L**, showing two repeat units.

(2)

(iii) Name the type of polymerization that results in the formation of **L**.

(1)

(iv) State the type of naturally occurring substance which contains the same type of linkage as in the polymer **L**.

(1)

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(c) If the sequence of reactions, that produces polymer *L* from tranexamic acid, is carried out starting with the *cis* isomer of tranexamic acid, an organic compound, **M**, is formed.

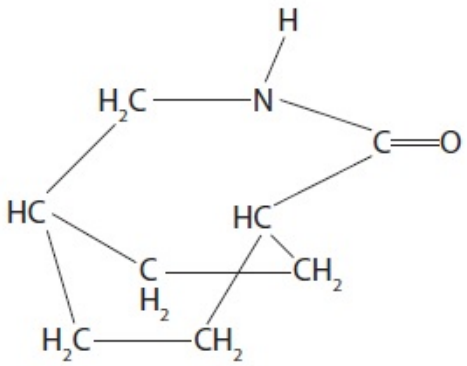
The low resolution nuclear magnetic resonance (nmr) spectrum of **M** has six peaks with relative heights 4:4:2:1:1:1.

The infrared (IR) spectrum of **M** has peaks in the region 1700−1630 cm^{-1} and 3500−3140 cm^{-1}.

(i) The structure of **M** is shown below.

The nmr spectrum shows that the molecule, **M**, has six different hydrogen environments. Use the letters **a** to **f** to label the H atoms of **M** showing the six hydrogen environments. All thirteen hydrogen atoms should be labelled.

(4)



(ii) Explain how the IR data are consistent with the structure of **M**.

(2)

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(iii) Suggest why **M** is formed from the *cis* isomer but not from the *trans* isomer.

(2)

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