AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level CHEMISTRY

Paper 2 Organic and Physical Chemistry

Tuesday 12 June 2018 Afternoon Time allowed: 2 hours

Materials

For this paper you must have:
- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on the blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 105.

For Examiner's Use	
Question	Mark
1	
2	
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8	
9	
10	
11	
TOTAL	

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Answer **all** questions in the spaces provided.

0 1 This question is about the reactions of alkanes.

0 1 . 1 Alkanes can be used as fuels.

Give an equation for the combustion of heptane (C_7H_{16}) in an excess of oxygen.

[1 mark]

0 1 . 2 Heptane can be obtained from the catalytic cracking of hexadecane ($C_{16}H_{34}$) at a high temperature.

Identify a suitable catalyst for this process.
Give **one** condition other than high temperature.
Give an equation for the catalytic cracking of one molecule of hexadecane to produce one molecule of heptane, one molecule of cyclohexane and one other product.

[3 marks]

Catalyst

Condition

Equation

0 1 . 3 Alkanes can be used in free-radical substitution reactions to produce halogenoalkanes.

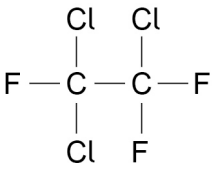
Give equations for the propagation steps in the reaction of butane to form 2-chlorobutane.

[2 marks]

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0 1 . 4 Chlorofluorocarbons (CFCs) are a group of halogenoalkanes currently banned in many countries. They cannot be used as solvents or refrigerants because of their effect on the environment.

The structure of a CFC is shown.



Identify the radical produced from this CFC that is responsible for the depletion of ozone in the atmosphere.
Explain, with the aid of equations, why a single radical can cause the decomposition of many molecules of ozone.

[4 marks]

Radical _____

Explanation _____

_____

_____

_____

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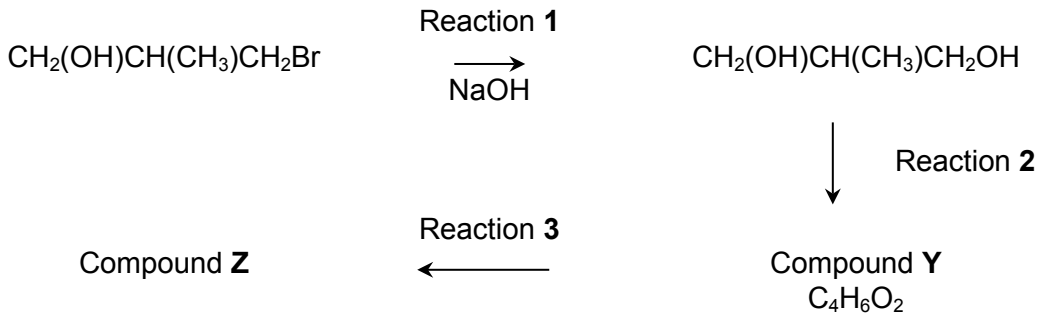
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Turn over for the next question

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0 2 Halogenoalkanes are useful compounds in synthesis. A reaction pathway is shown.



0 2 . 1 Give the IUPAC name for $CH_2(OH)CH(CH_3)CH_2Br$

[1 mark]

0 2 . 2 Reaction **1** occurs via a nucleophilic substitution mechanism.

Explain why the halogenoalkane is attacked by the nucleophile in this reaction.

[3 marks]

Do not write outside the box

0 2 . 3 The infrared spectrum of Compound **Y** shows a significant absorption in the range 1680–1750 cm^{-1}

Draw the displayed formula of Compound **Y**.

[1 mark]

0 2 . 4 Compound **Z** has the empirical formula C_3H_4NO

Give the structure of Compound **Z**.
Suggest the reagent for Reaction **3**.

[2 marks]

Structure

Reagent for Reaction **3** _____

7

Do not write outside the box

0 3 The oxidation of propan-1-ol can form propanal and propanoic acid.
The boiling points of these compounds are shown in **Table 1**.

Table 1

Compound	Boiling point / °C
propan-1-ol	97
propanal	49
propanoic acid	141

In a preparation of propanal, propan-1-ol is added dropwise to the oxidising agent and the aldehyde is separated from the reaction mixture by distillation.

0 3 . 1 Explain, with reference to intermolecular forces, why distillation allows propanal to be separated from the other organic compounds in this reaction mixture.

[3 marks]

Do not write outside the box

0 3 . 2 Give **two** ways of maximising the yield of propanal obtained by distillation of the reaction mixture.

[2 marks]

1 _____

2 _____

0 3 . 3 Describe how you would carry out a simple test-tube reaction to confirm that the sample of propanal obtained by distillation does **not** contain any propanoic acid.

[2 marks]

Question 3 continues on the next page

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0 3 . 4 A student carried out an experiment to determine the enthalpy of combustion of ethanol.
Combustion of 457 mg of ethanol increased the temperature of 150 g of water from 25.1 °C to 40.2 °C

Calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of ethanol in this experiment.
Give your answer to the appropriate number of significant figures.

(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

[3 marks]

Enthalpy of combustion _____ kJ mol^{-1}

Do not write outside the box

0 3 . 5 A mixture of isomeric alkenes is produced when pentan-2-ol is dehydrated in the presence of hot concentrated sulfuric acid. Pent-1-ene is one of the isomers produced.

Name and outline a mechanism for the reaction producing pent-1-ene.

[4 marks]

Name of mechanism _____

Mechanism

0 3 . 6 A pair of stereoisomers is also formed in the reaction in Question **03.5**.

Name the less polar stereoisomer formed.
Explain how this type of stereoisomerism arises.

[2 marks]

Name _____

Explanation _____

_____

_____

_____

16

Do not write outside the box

0 4 Compounds **A** and **B** react together to form an equilibrium mixture containing compounds **C** and **D** according to the equation

$$2\mathbf{A} + \mathbf{B} \rightleftharpoons 3\mathbf{C} + \mathbf{D}$$

0 4 . 1 A beaker contained 40 cm^3 of a 0.16 mol dm^{-3} aqueous solution of **A**.
9.5×10^{-3} mol of **B** and 2.8×10^{-2} mol of **C** were added to the beaker and the mixture was left to reach equilibrium.
The equilibrium mixture formed contained 3.9×10^{-3} mol of **A**.

Calculate the amounts, in moles, of **B**, **C** and **D** in the equilibrium mixture.

[5 marks]

Amount of **B** _____ mol

Amount of **C** _____ mol

Amount of **D** _____ mol

0 4 . 2 Give the expression for the equilibrium constant (K_c) for this equilibrium **and** its units.

[2 marks]

K_c

Units _____

Do not write outside the box

0 4 . 3 A different equilibrium mixture of these four compounds, at a different temperature, contained 0.21 mol of **B**, 1.05 mol of **C** and 0.076 mol of **D** in a total volume of 5.00×10^2 cm^3 of solution.
At this temperature the numerical value of K_c was 116

Calculate the concentration of **A**, in mol dm^{-3}, in this equilibrium mixture.
Give your answer to the appropriate number of significant figures.

[3 marks]

Concentration of **A** _____ mol dm^{-3}

0 4 . 4 Justify the statement that adding more water to the equilibrium mixture in Question **04.3** will lower the amount of **A** in the mixture.

[3 marks]

_____

_____

_____

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13

Turn over ►

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ANSWER IN THE SPACES PROVIDED

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0 5 Bromate(V) ions and bromide ions react in acid conditions according to the equation

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

0 5 . 1 A series of experiments was carried out at a given temperature. The results were used to deduce the rate equation for the reaction.

$$rate = k\,[BrO_3^-][Br^-][H^+]^2$$

Table 2 shows an incomplete set of results.

Table 2

Experiment	Initial $[BrO_3^-]$ / mol dm^{-3}	Initial $[Br^-]$ / mol dm^{-3}	Initial $[H^+]$ / mol dm^{-3}	Initial rate of reaction / mol dm^{-3} s^{-1}
1	0.10	0.20	0.30	2.4×10^{-2}
2		0.20	0.30	3.6×10^{-2}
3	0.20	0.40	0.50	
4	0.10	0.10		2.7×10^{-2}

Use the data from Experiment **1** to calculate a value for the rate constant, *k*, at this temperature and give its units.

Give your answer to an appropriate number of significant figures.

[3 marks]

k _____ Units _____

0 5 . 2 Complete **Table 2**.

[3 marks]

Space for working

Question 5 continues on the next page

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0 5 . 3 A second series of experiments was carried out to investigate how the rate of the reaction varies with temperature.
The results were used to obtain a value for the activation energy of the reaction, E_a

Identical amounts of reagents were mixed at different temperatures.
The time taken, t, for a fixed amount of bromine to be formed was measured at different temperatures.

The results are shown in **Table 3**.

Table 3

Temperature, T / K	$\frac{1}{T}$ **/ K^{-1}**	**Time, t / s**	$\frac{1}{t}$ **/ s^{-1}**	**ln $\frac{1}{t}$**
286	3.50×10^{-3}	54	1.85×10^{-2}	−3.99
295	3.39×10^{-3}	27	3.70×10^{-2}	
302		15	6.67×10^{-2}	−2.71
312	3.21×10^{-3}	8	1.25×10^{-1}	−2.08

Complete **Table 3**.

[2 marks]

0 5 . 4 The Arrhenius equation can be written as

$$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + C_1$$

In this experiment, the rate constant, k, is directly proportional to $\frac{1}{t}$

Therefore

$$\ln \frac{1}{t} = -\frac{E_a}{R}\left(\frac{1}{T}\right) + C_2$$

where C_1 and C_2 are constants.

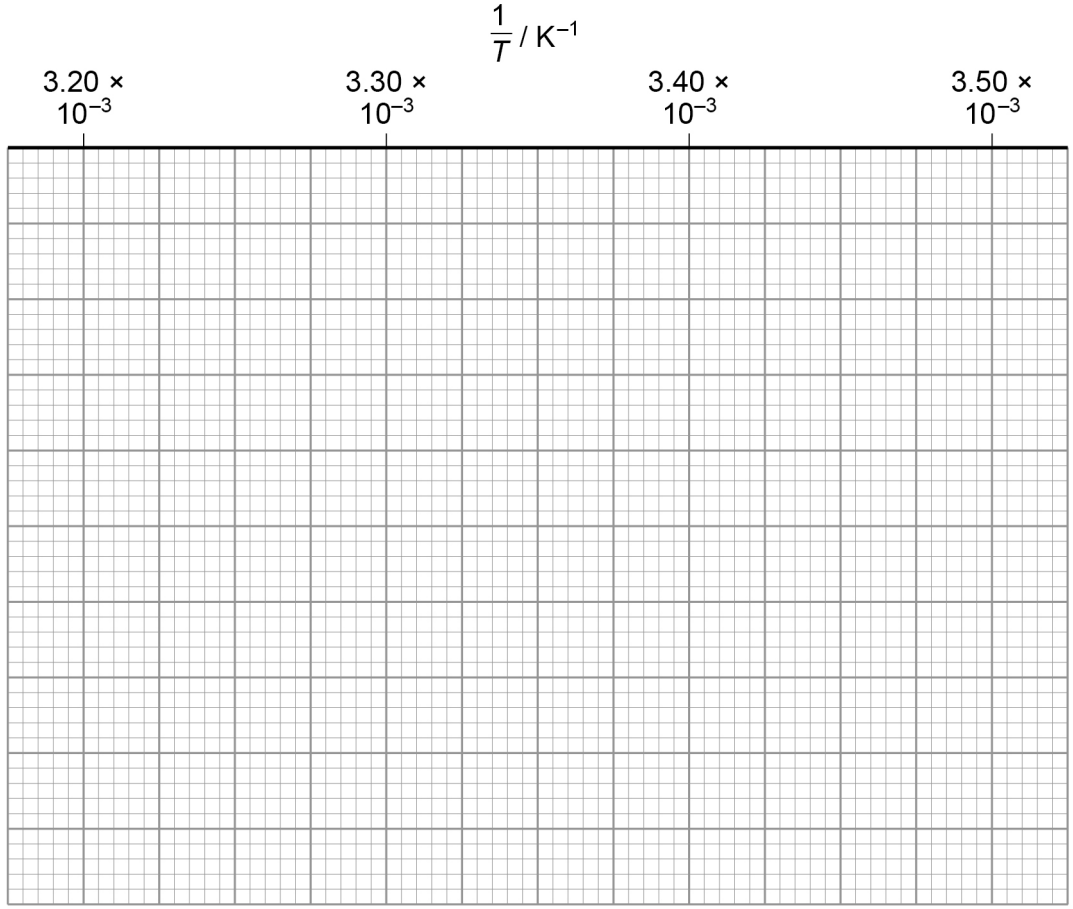
Use values from **Table 3** to plot a graph of ln $\frac{1}{t}$ (y axis) against $\frac{1}{T}$ on the grid.

Use your graph to calculate a value for the activation energy, in kJ mol^{-1}, for this reaction.

The value of the gas constant, $R = 8.31$ J K^{-1} mol^{-1}

[6 marks]

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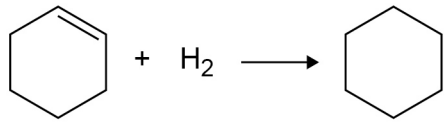


Activation energy _____ kJ mol^{-1}

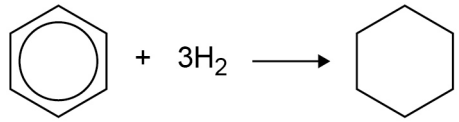
14

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0 6 Data about the hydrogenation of cyclohexene and of benzene are given.



$\Delta H^{\ominus} = -120 \text{ kJ mol}^{-1}$



$\Delta H^{\ominus} = -208 \text{ kJ mol}^{-1}$

0 6 . 1 Explain the bonding in and the shape of a benzene molecule.
Compare the stability of benzene with that of the hypothetical cyclohexa-1,3,5-triene molecule.
Use the data in your answer.

[6 marks]

Do not write outside the box

0 6 . 2 The enthalpy of hydrogenation of cyclohexa-1,3-diene is **not** exactly double that of cyclohexene.

Suggest a value for the enthalpy of hydrogenation of cyclohexa-1,3-diene and justify your value.

[3 marks]

9

Do not write outside the box

0 7 Acyl chlorides are useful reagents in synthesis. They react with aromatic compounds and also with alcohols.

0 7 . 1 CH_3CH_2COCl reacts with benzene in the presence of $AlCl_3$ in an electrophilic substitution reaction.

Give an equation for the reaction of CH_3CH_2COCl with $AlCl_3$ to form the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

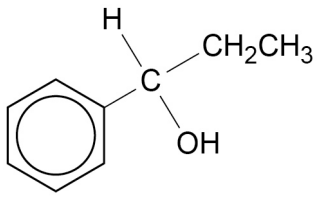
[4 marks]

Equation _____

Mechanism

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0 7 . 2 The organic product in Question **07.1** can be converted into the alcohol shown.



Give the IUPAC name of the alcohol.
Give the reagent needed for this reaction and name the mechanism.

[3 marks]

IUPAC name _____

Reagent _____

Name of mechanism _____

0 7 . 3 The alcohol shown in Question **07.2** reacts with ethanoyl chloride to form an ester.

Describe what would be observed when the alcohol reacts with ethanoyl chloride.
Name the mechanism for the reaction to form the ester.
Draw the structure of the ester.

[3 marks]

Observation _____

_____

Name of mechanism _____

Structure of ester

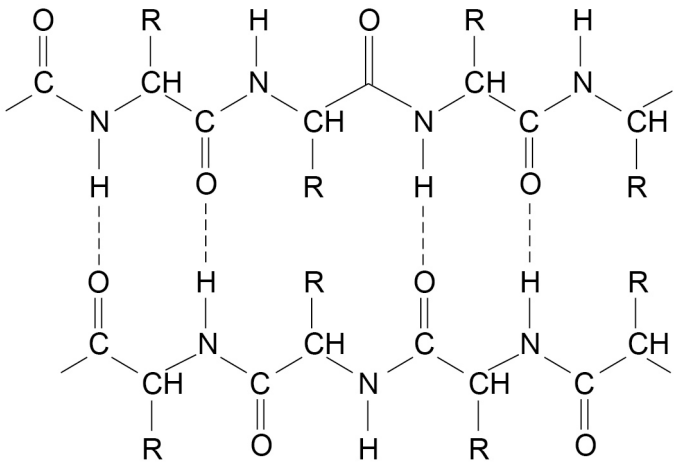
10

Turn over for the next question

Do not write outside the box

0 8 Use the Data Booklet to help you answer this question about amino acids.
Figure 1 shows parts of two polypeptide chains in a beta-pleated sheet of a protein.

Figure 1



0 8 . 1 The polypeptide chains are held together by hydrogen bonding as shown in **Figure 1**.

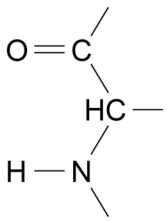
Explain how these hydrogen bonds form.

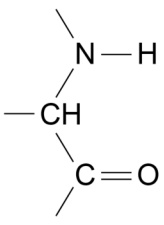
[2 marks]

0 8 . 2 A different type of bond can form between two polypeptide chains when the chains each contain the amino acid cysteine.

Complete the structure to show the bond that forms between the side chains of two cysteine molecules.

[1 mark]





Do not write outside the box

0 8 . 3 The type of bond in Question **08.2** between two polypeptide chains influences the three-dimensional structure of the protein.

Name this type of protein structure.

[1 mark]

_____

0 8 . 4 Draw the structure of the zwitterion of a dipeptide formed by alanine and serine.

[2 marks]

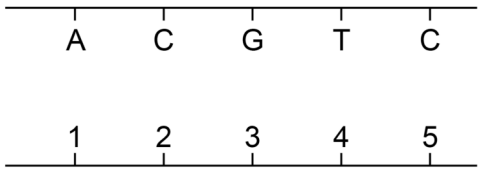
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Turn over for the next question

Do not write outside the box

0 9 Use the Data Booklet to help you answer this question about DNA.
Figure 2 shows a fragment of a DNA double helix.
The letters A, C, G and T represent the four bases in one strand.
The numbers 1, 2, 3, 4 and 5 represent the bases in the complementary strand.

Figure 2



0 9 . 1 Complete **Table 4** to show the correct sequence of bases in the complementary strand represented by the numbers 1 to 5

[1 mark]

Table 4

1	2	3	4	5

0 9 . 2 Deduce the total number of hydrogen bonds formed between the five bases in each strand.

Tick (✓) **one** box.

[1 mark]

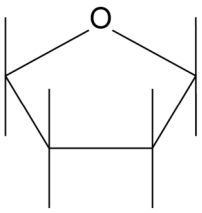
10	12	13	15

Do not write outside the box

0 9 . 3 Base A is part of a nucleotide in the DNA strand shown in **Figure 2**.
A nucleotide contains a 2-deoxyribose molecule.
An incomplete 2-deoxyribose molecule is shown.

Complete the structure to show the nucleotide that contains base A.
You should represent base A by the letter A.

[2 marks]



4

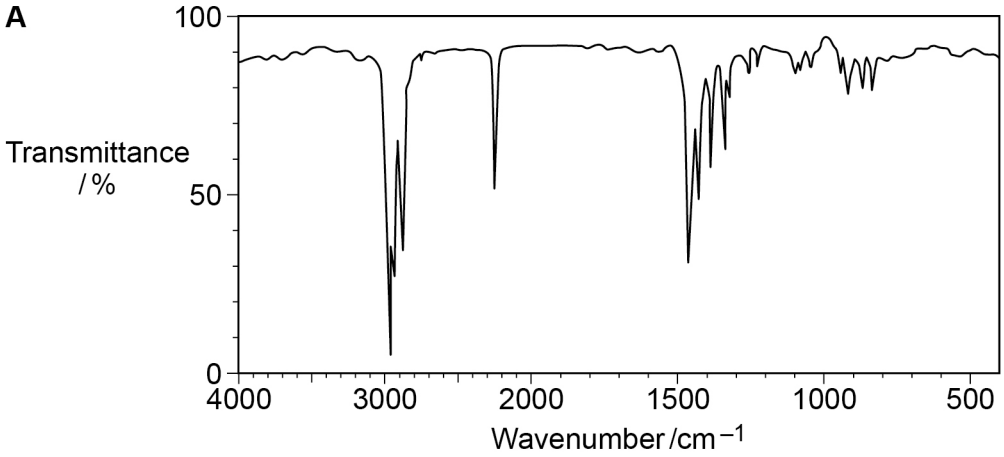
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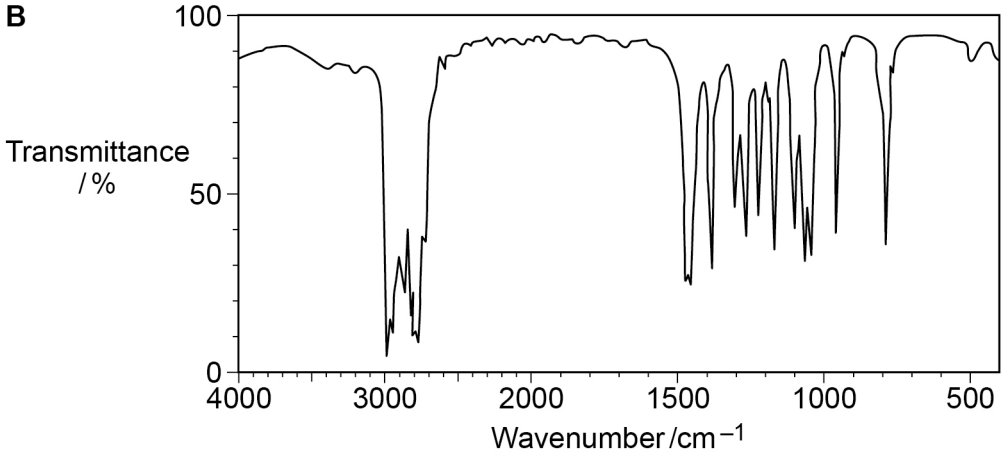
1 0 This question is about amines.

1 0 . 1 The infrared spectra **A**, **B** and **C** are those of a primary amine, a tertiary amine and a nitrile, but not necessarily in that order.

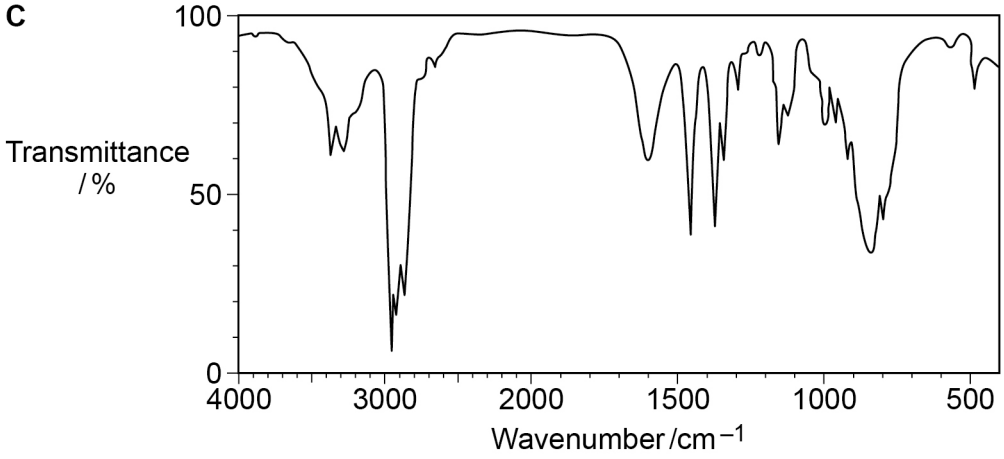
A



B



C



Give the letter of each compound in the correct box.

[1 mark]

primary amine	tertiary amine	nitrile

Do not write outside the box

1 0 . 2 There are **three** secondary amines that contain four carbon atoms per molecule.

Draw the skeletal formulas of these **three** secondary amines.

[2 marks]

1 0 . 3 Primary amines can be prepared by the reaction of halogenoalkanes with ammonia or by the reduction of nitriles.

Justify the statement that it is better to prepare primary amines from nitriles rather than from halogenoalkanes.

[2 marks]

1 0 . 4 Draw the structure of a primary amine with four carbon atoms that **cannot** be formed from a nitrile.

[1 mark]

Do not write outside the box

1 0 . 5 A student dissolves a few drops of propylamine in 1 cm^3 of water in a test tube.

Give an equation for the reaction that occurs.
Describe what is observed when Universal Indicator is added to this solution.

[2 marks]

Equation _____

Observation _____

_____

_____

1 0 . 6 Phenylamine can be prepared by a process involving the reduction of nitrobenzene using tin and an excess of hydrochloric acid.

Give an equation for the reduction of nitrobenzene to form phenylamine. Use [H] to represent the reducing agent.
Explain why an aqueous solution is obtained in this reduction even though phenylamine is insoluble in water.

[2 marks]

Equation _____

Explanation _____

_____

_____

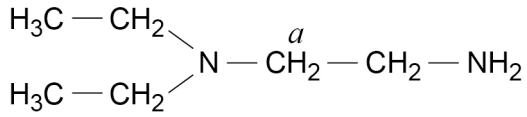
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1 1 There are several isomers with the molecular formula $C_6H_{16}N_2$

1 1 . 1 One isomer is shown.



Give the number of peaks in the ^{13}C NMR spectrum of this isomer.

State and explain the splitting pattern of the peak for the hydrogens labelled *a* in its ^{1}H NMR spectrum.

[3 marks]

Number of ^{13}C peaks _____

Splitting pattern _____

Explanation _____

_____

_____

_____

1 1 . 2 Draw the structure of the isomer of $C_6H_{16}N_2$ used to make nylon 6,6

[1 mark]

Question 11 continues on the next page

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1 1 . 3 Draw the structure of the isomer of $C_6H_{16}N_2$ that contains two **primary** amine groups and has only two peaks in its ^{13}C NMR spectrum.

[1 mark]

1 1 . 4 Draw the structure of the isomer of $C_6H_{16}N_2$ that contains two **tertiary** amine groups and has only two peaks in its ^{13}C NMR spectrum.

[1 mark]

END OF QUESTIONS

6

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