# Chemistry Mock 3.B Revision Pack

| Question | Maximum Mark | Mark Awarded |
|---|---|---|
| #1 | 15 | |
| #2 | 7 | |
| #3 | 6 | |
| #4 | 6 | |
| #5 | 9 | |
| #6 | 10 | |
| #7 | 6 | |
| #8 | 6 | |
| #9 | 16 | |
| #10 | 4 | |
| #11 | 2 | |
| #12 | 1 | |
| #13 | 5 | |
| #14 | 5 | |
| #15 | 6 | |
| #16 | 11 | |
| #17 | 5 | |

| | |
|---|---|
| #18 | 7 |
| #19 | 6 |
| Total | 133 |

#1

**10.** *(a)* A student is asked to prepare a sample of ethanal by oxidising ethanol.

(i) Write an equation for this reaction. [1]

Use [O] to represent the oxidising agent and show the structure of the organic product.

(ii) Describe, giving brief experimental details, how he can carry out the reaction. [4]

.....

.....

.....

.....

.....

.....

.....

.....

(iii) Ethanol can also be oxidised to ethanoic acid. Describe how the student could use a chemical test to confirm that his sample of ethanal did **not** contain ethanoic acid. [2]

.....

.....

.....

*(b)* State a difference and a similarity between the $^{13}C$ NMR spectra of ethanal and ethanol. [2]

Difference .....

.....

Similarity .....

.....

*(c)* Ethanol is widely used as a biofuel in some countries.

(i) The equation for its combustion is given below.

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

Use the average bond enthalpy values given in the table below to calculate the enthalpy of combustion for ethanol. [3]

| Bond | Average bond enthalpy / kJ $mol^{-1}$ |
|---|---|
| C—C | 348 |
| C—H | 412 |
| C—O | 360 |
| O—H | 463 |
| O=O | 496 |
| C=O | 743 |

$\Delta_c H$ ethanol = ..... kJ $mol^{-1}$

(ii) Give a disadvantage of biofuels compared with fossil-based fuels. [1]

.....

.....

*(d)* Ethanol and hexan-1-ol are both primary alcohols. Explain why ethanol is soluble in water but hexan-1-ol is not. [2]

.....

.....

.....

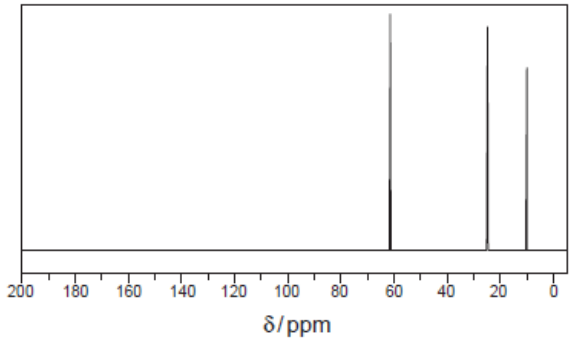
#2

*(a)* Compound **X** is an alcohol. When compound **X** is warmed with acidified potassium dichromate(VI) there is a colour change.

In the mass spectrum of compound **X**

- the molecular ion peak is at m/z 74
- the peak with the greatest relative intensity is at m/z 43 and is due to a secondary carbocation

Compound **X** has the following $^{13}C$ NMR spectrum.




Explain what can be deduced from each piece of information and identify the structure of compound **X**. [7]

Structure of compound **X**

Question taken from Eduqas examination paper 841002, November 2020

#3

*(d)* Under suitable conditions dichloroethanoic acid, $Cl_2CHCOOH$, reacts with alkalis to give compound **W**.

Information about compound **W** is given below.

- It has a relative molecular mass of 74
- There are three oxygen atoms in each molecule
- Its $^{1}H$ NMR spectrum shows signals at 9.5 and 11.0 ppm
- An aqueous solution turns Universal Indicator paper from green to red
- Its $^{13}C$ NMR spectrum shows only two signals

Use **all** of this information to deduce a structure for compound **W** giving reasons for your answer. [6]

.....

.....

.....

.....

.....

.....

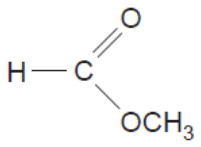
.....

.....

Question taken from Eduqas examination paper 841102, October 2021

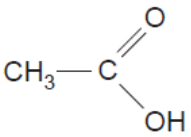
#4

(a) The following compounds are isomers of formula $C_2H_4O_2$.



methyl methanoate

boiling temperature 32°C



ethanoic acid

boiling temperature 118°C

Compare these compounds referring to their

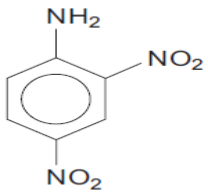
- reactions with sodium hydrogencarbonate and universal indicator
- relative boiling temperatures
- $^1$H NMR spectra

In each case you should explain any differences. [6 QER]

Question taken from Eduqas examination paper 841102, June 2023

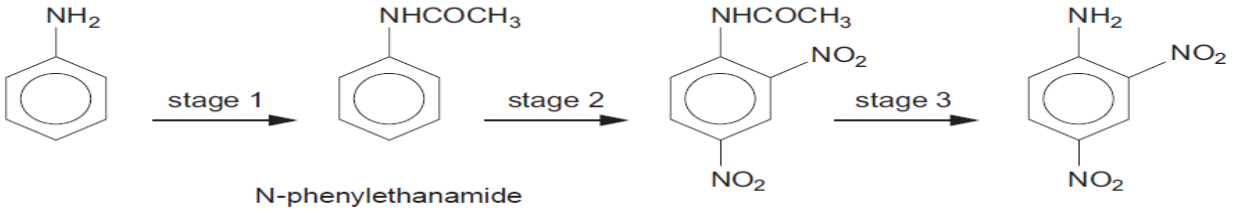
#5

*(a)* Derivatives of 2,4-dinitrophenylamine have been used as herbicides for about 80 years.




2,4-dinitrophenylamine

One method of preparing this compound is from phenylamine.



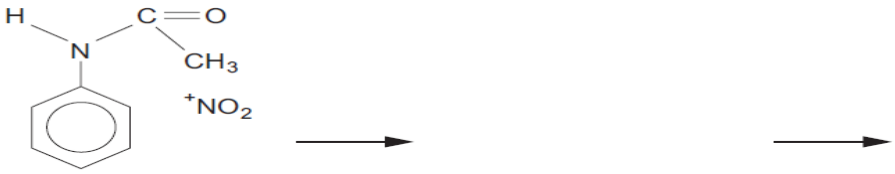

N-phenylethanamide

(i) State the reagent used in stage 1 to produce N-phenylethanamide from phenylamine. [1]

.....

(ii) N-phenylethanamide is nitrated by using a mixture of concentrated nitric and sulfuric acids, in the same way as in the nitration of benzene.

Complete the mechanism below to produce 2-nitro-N-phenylethanamide, where just one nitro group has been substituted into the ring. You should include curly arrows, appropriate charges and the formulae of the intermediate and final products. [3]




(iii) By analogy with the nitration of benzene suggest how you could modify the nitration reaction in (ii) to ensure that the dinitro- product is formed. [1]

.....

.....

(iv) 2,4-Dinitrophenylamine has a melting temperature of 180 °C and is recrystallised from a 1:1 mixture of ethanol and water. Outline the essential stages of this recrystallisation process so that pure dry crystals of 2,4-dinitrophenylamine are obtained. You should assume that a hot water bath is available for use. [4]

.....

.....

.....

.....

.....

.....

.....

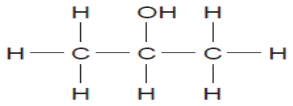
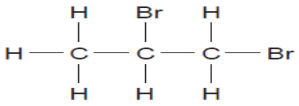
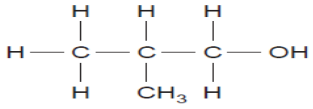
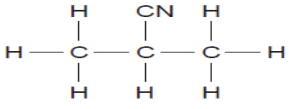
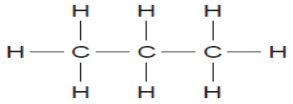
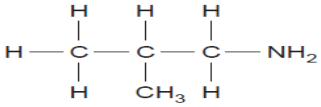
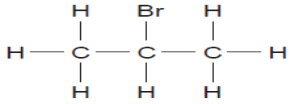
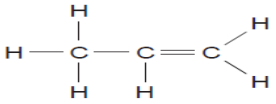
Question taken from Eduqas examination paper 841102, June 2017

#6

You are required to show how **each** of the eight compounds (**A**–**H**) below can be formed from any one of the other seven compounds.

Complete the table opposite, giving the **letter** of the starting compound, the reagent(s) and any necessary reaction conditions.

You may use each starting compound once, more than once or not at all. [10]

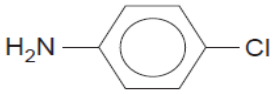
| | | | |
|---|---|---|---|
| **A** |  | **B** |  |
| **C** |  | **D** |  |
| **E** |  | **F** |  |
| **G** |  | **H** |  |

| Starting compound | Product | Reagent(s) | Conditions |
|---|---|---|---|
| | **A** | | |
| | **B** | | |
| | **C** | | |
| | **D** | | |
| | **E** | | |
| | **F** | | |
| | **G** | | |
| | **H** | | |

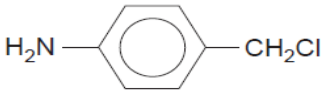
Question taken from Eduqas examination paper 841103, June 2023

#7

(b) (i) Explain why 4-chlorophenylamine does not react readily with aqueous sodium hydroxide but (4-chloromethyl)phenylamine produces (4-hydroxymethyl)phenylamine when treated with the same reagent.




4-chlorophenylamine




(4-chloromethyl)phenylamine

You should refer to both compounds in your answer. [2]

.....

.....

.....

.....

.....

.....

(ii) 4-Chlorophenylamine reacts with nitric(III) acid (produced from sodium nitrate(III) and hydrochloric acid) to give a diazonium compound.

This can then react with phenol to give an azo dye.

I. State the temperature necessary to produce a diazonium compound. [1]

..... °C

II. Give the structure of the azo dye produced in this reaction. [1]

III. Another azo dye, Solvent Yellow 7, has a maximum absorption in its UV-visible spectrum at a wavelength of 347 nm.

Calculate the frequency of this maximum absorption. [2]

Frequency = ..... Hz

Question taken from Eduqas examination paper 841102, June 2022

#8

*(d)* (i) Phenylamine is made in the laboratory by the reduction of nitrobenzene.

State the reagents used for this reduction. [1]

.....

(ii) The direct nitration of phenylamine gives a mixture of products as well as the required nitrophenylamine.

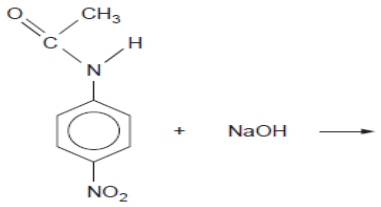
To obtain a better yield of nitrophenylamine, phenylamine is firstly converted to N-phenylethanamide.

State a reagent that could be used for this reaction. [1]

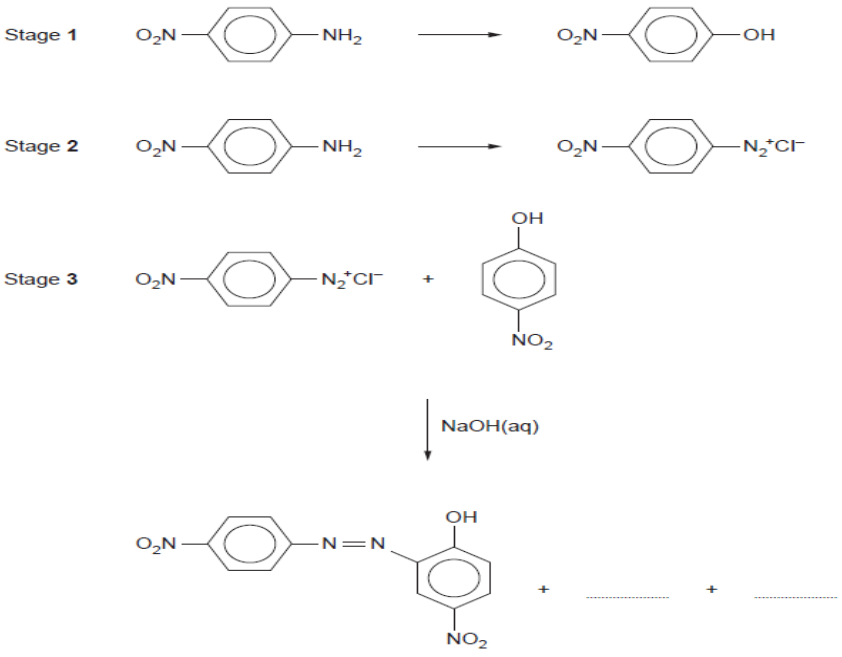
.....

(iii) Nitration of N-phenylethanamide gives N-(4-nitrophenyl)ethanamide which is then reacted with aqueous sodium hydroxide to give 4-nitrophenylamine.

Complete the equation for this reaction. [1]



*(e)* A method for making an azo dye from 4-nitrophenylamine is shown below.




(i) State the temperature used for

Stage **1** .....

Stage **2** ..... [2]

(ii) **Complete the equation** shown in stage **3** by giving the formulae of the other products formed. [1]

Question taken from Eduqas examination paper 841102, November 2020

#9

**13.** *(a)* Explain why amino acids are amphoteric compounds. [1]

.....

*(b)* If an amino acid is treated with methanal, the resulting compound can be titrated against sodium hydroxide solution in a 1:1 ratio.

4.95 g of an amino acid was treated with methanal and the resulting solution made up to 250 $cm^3$. 25.0 $cm^3$ of this solution was then titrated with sodium hydroxide of concentration 0.105 mol $dm^{-3}$. The results are shown in the table below.

| Titration | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| NaOH(aq) used / $cm^3$ | 38.70 | 35.90 | 36.00 | 32.00 | 36.10 |

(i) Suggest a practical reason why the reading for titration 1 was too high. [1]

.....

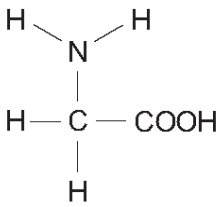
.....

(ii) Use appropriate titration values to calculate the relative molecular mass of the amino acid. [5]

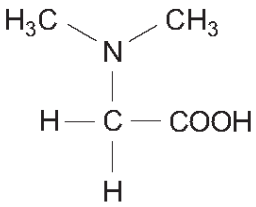
$M_r$ = .....

(iii) Assuming that the amino acid in part (ii) is a straight chain aliphatic $\alpha$-amino acid deduce its structure. [2]

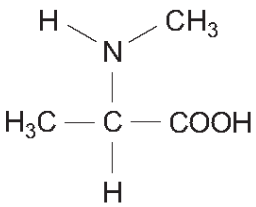
*(c)* The formulae of three amino acids are shown below.



compound **R**



compound **S**



compound **T**

(i) State which of the three compounds could be identified by its ability to rotate the plane of plane polarised light. Give a reason for your answer. [1]

.....

.....

(ii) State how the infrared absorption spectrum of compounds **S** and **T** would differ from each other in their significant functional group absorption(s). [1]

.....

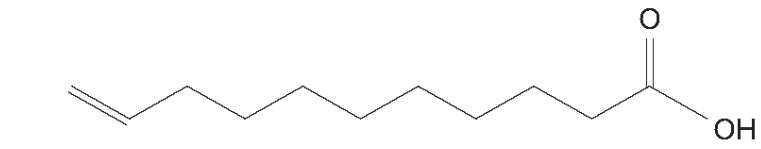
.....

(iii) State which of these amino acids would **not** be able to form two **different** dipeptides with either of the other two amino acids. Explain your answer. [1]

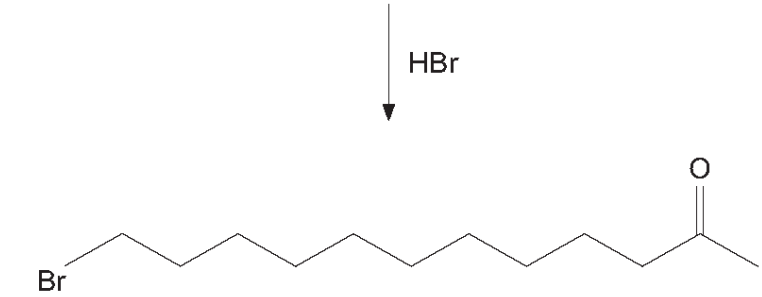
.....

.....

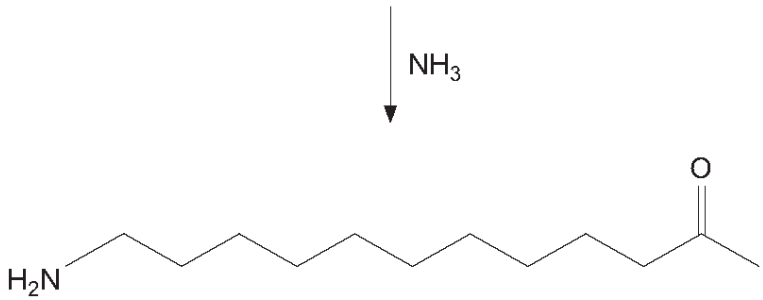
*(d)* Nylon-11 is a bio-sourced polyamide which is made from castor oil. Undec-10-enoic acid is produced as an intermediate compound. This acid is reacted, under suitable conditions, to give 11-bromoundecanoic acid, which is then treated with ammonia to produce 11-aminoundecanoic acid. Polymerisation of this product gives nylon-11.




undec-10-enoic acid




11-bromoundecanoic acid




11-aminoundecanoic acid

(i) The addition of hydrogen bromide to undec-10-enoic acid would give 10-bromoundecanoic acid as the major product. Explain why this is the case. [1]

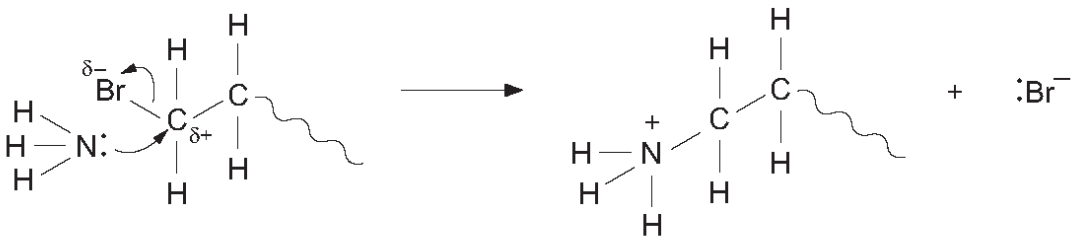
.....

.....

.....

(ii) The bromo-compound reacts with ammonia to produce 11-aminoundecanoic acid.

One step in the mechanism for this reaction is shown below.



I. Explain how partial charges (δ+ and δ–) arise on the carbon and bromine atoms. [1]

.....

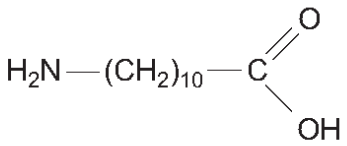
.....

II. State the role of ammonia in this reaction. [1]

.....

(iii) Draw the structure of nylon-11, indicating the repeating unit present.

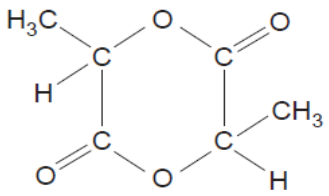
The formula of 11-aminoundecanoic acid is shown below. [1]



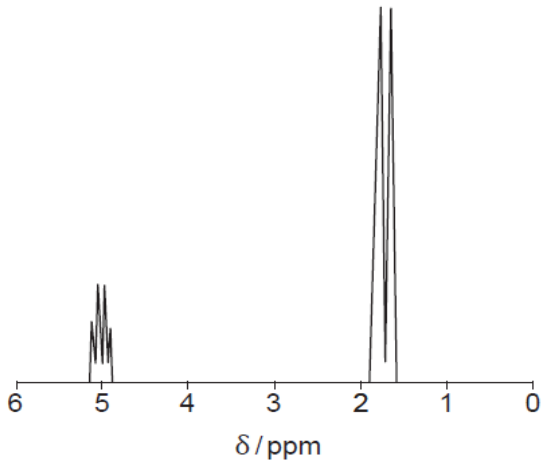
Question taken from Eduqas examination paper 841102, June 2018

#10

(e) Lactic acid forms a 'lactide' by elimination of water between two molecules of the acid.




(i) A simplified high resolution $^1$H NMR spectrum of this 'lactide' is shown below.




Use the structure of the 'lactide' to explain the splitting pattern seen in the NMR spectrum. [2]

.....

.....

.....

(ii) The infrared absorption spectrum of the 'lactide' shows strong absorptions at 1266 $cm^{-1}$ and at 1750 $cm^{-1}$.

Use the **Data Booklet** and the structure of the 'lactide' to identify the bonds responsible for these absorptions in the 'lactide'. [1]

.....

.....

(iii) The 'lactide' is an intermediate in the formation of poly(lactic acid). The polymerisation occurs using a tin(II) octanoate catalyst.

Give the formula of tin(II) octanoate. [1]

.....

Question taken from Eduqas examination paper 841102, June 2023

#11

*(e)* 1,4-Di(hydroxymethyl)benzene, $HOH_2C–C_6H_4–CH_2OH$, and benzene-1,4-dicarboxylic acid, $HOOC–C_6H_4–COOH$, react together to give a polyester.

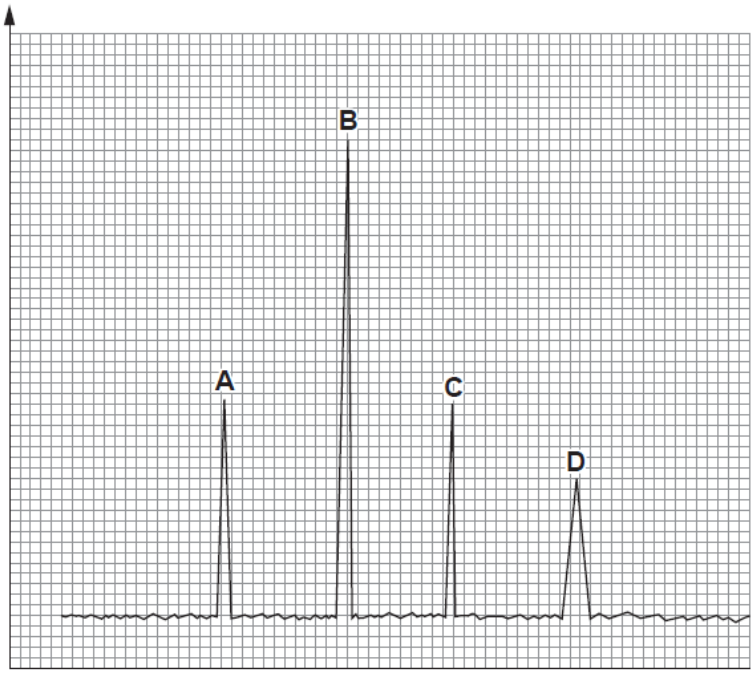
(i) Use the formula of these two compounds to give the formula of the repeating section of this polyester. [1]

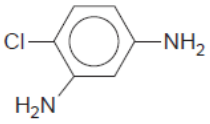
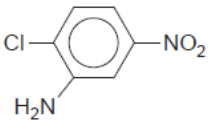
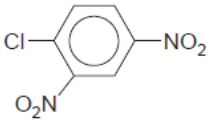
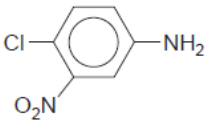
(ii) Draw a ring around the part of the repeating section in part (i) that shows the ester linkage in this polymer. [1]

Question taken from Eduqas examination paper 841102, October 2021

#12

(b) The diagram shows a gas chromatogram of the products obtained by the reduction of 1-chloro-2,4-dinitrobenzene.




| Letter | Compound | Relative peak area | Letter | Compound | Relative peak area |
|---|---|---|---|---|---|
| **A** |  | 32 | **C** |  | 31 |
| **B** |  | 59 | **D** |  | 38 |

Calculate the percentage (by volume) of the fully reduced product, 1-chlorobenzene-2,4-diamine. [1]

Percentage = ..... %

Question taken from Eduqas examination paper 841102, June 2023

#13

(b) (i) The addition of a solute to a solvent gives a solution that has a lower freezing temperature than the pure solvent. The freezing temperature obtained can be used to find the relative molecular mass of the solute.

In a modification to this method 0.698 g of a substituted amide, **R**–CONH($C_6H_5$), was mixed with 5.00 g of camphor and the freezing temperature of the mixture found.

Pure camphor freezes at 179 °C and the freezing temperature of the mixture was 145 °C.

Use the formula below to work out the relative molecular mass ($M_r$) of the amide. [1]

$$\Delta T = \frac{1000 \times w \times k}{W \times M_r}$$

where $\Delta T$ is the lowering of the freezing temperature
$w$ is the mass of the substituted amide
$W$ is the mass of camphor
$k$ is 39.7

$M_r$ = .....

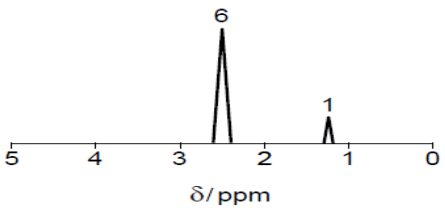
(ii) Use the answer to part (i) to show that '$M_r$' for the **R** group is 43. [1]

(iii) **R** represents the formula of a saturated hydrocarbon chain.

Deduce a molecular formula for the **R** group. [1]

**R** is .....

(iv) The diagram shows the low resolution $^1$H NMR spectrum of the **R** group.




Use the spectrum to deduce the structure of the **R** group. Explain your answer. [2]

.....

.....

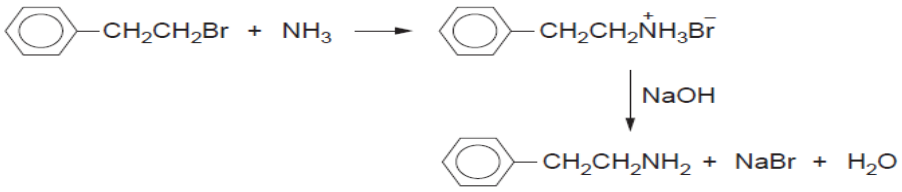
.....

.....

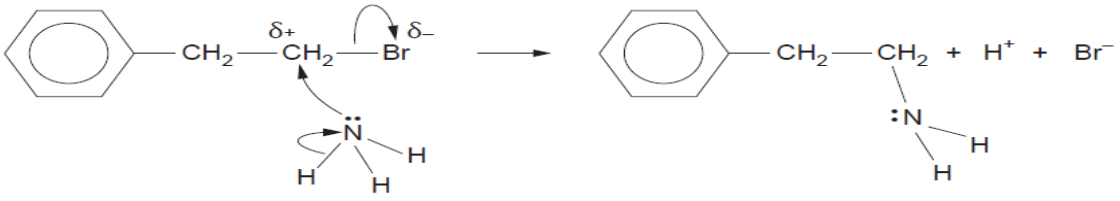
Question taken from Eduqas examination paper 841102, June 2022

#14

(b) (2-Bromoethyl)benzene reacts with ammonia.



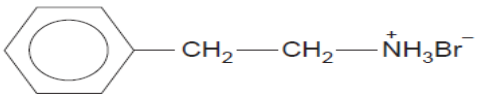

A simplified mechanism for this reaction is shown below.




(i) State the type of reaction mechanism occurring. [1]

.....

(ii) The initial product of this reaction is the compound whose formula is shown below.

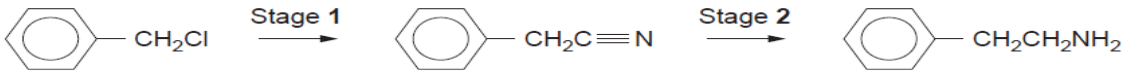



Explain why this salt is formed rather than 2-phenylethylamine and hydrogen bromide. [1]

.....

.....

(iii) 2-Phenylethylamine can also be produced from (chloromethyl)benzene.




I. State the reagent used in Stage **1**. [1]

.....

II. Use the **Data Booklet** to explain how the infrared absorption value at 2100-2250 $cm^{-1}$ changes during Stage **2**. [1]

.....

.....

III. State the type of reaction occurring in Stage **2**. [1]

.....

Question taken from Eduqas examination paper 841102, June 2023

#15

*(f)* Compound **J** is a polyamide that is produced from two different monomers. This polyamide is hydrolysed by boiling it with aqueous sodium hydroxide. After acidifying the mixture obtained from hydrolysis, compound **K**, a dicarboxylic acid of general formula $HOOC–(CH_2)_n–COOH$ is isolated from the mixture. 1.24 g of compound **K** is titrated against aqueous sodium hydroxide of concentration 0.500 mol $dm^{-3}$. 37.55 $cm^3$ are needed to just neutralise the acid.

Compound **L** is also formed from hydrolysis of the polyamide. It is a diamine, $H_2N–R–NH_2$, where R is a group containing only carbon and hydrogen. 0.500 g of this diamine reacts with nitric(III) acid to produce 278 $cm^3$ of nitrogen gas, measured at 298 K and 1 atm.

$$H_2N–(C_x\,H_{2x})–NH_2 \xrightarrow{\text{nitric (III) acid}} 2N_2 + \text{other products}$$

The $^{13}C$ NMR spectrum of compound **L** shows that the R group contains three different carbon environments.

Use the information provided to deduce the displayed formulae of compounds **K** and **L**, and hence give the formula of the repeating section of polyamide **J**. [6 QER]

Question taken from Eduqas examination paper 841102, June 2017

#16

*(e)* Compound **R** is a neutral saturated aliphatic compound that contains only carbon, hydrogen and oxygen. The percentage of oxygen by mass is 24.6. This compound is hydrolysed in acid solution to give two new organic compounds, **S** and **T**. Further information about **R**, **S** and **T** is given below.

Compound **R**

- The $^{13}C$ NMR spectrum shows that there are five different carbon environments
- The $^{1}H$ NMR spectrum shows the following signals

| Signal $\delta$/ppm | Relative peak area |
|---|---|
| 1.20 singlet | 9 |
| 1.25 triplet | 3 |
| 4.11 quartet | 2 |

- The infrared absorption spectrum shows a peak at 1731 $cm^{-1}$ but no peak at 2500–3550 $cm^{-1}$
- It is not an aldehyde or a ketone

Compound **S**

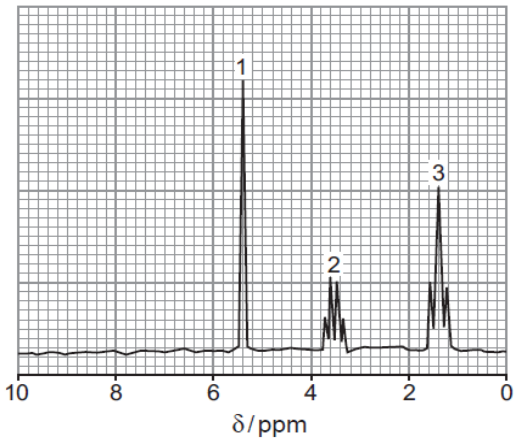
- The $^{13}C$ NMR spectrum shows that there are three different carbon environments
- The $^{1}H$ NMR spectrum shows the following signals

| Signal $\delta$/ppm | Relative peak area |
|---|---|
| 1.20 singlet | 9 |
| around 11 | 1 |

- An aqueous solution is weakly acidic

Compound **T**

- The $^{13}C$ NMR spectrum shows that there are two different carbon environments
- The $^{1}H$ NMR spectrum is shown below – relative peak areas 1, 2 and 3

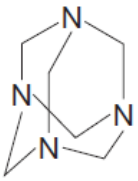



- The compound is neutral

Use this information to deduce the formulae of compounds **S** and **T** and hence the displayed formula of compound **R**.

It is not necessary to name any of the compounds. [11]

#17 *(a)* Hexamethylenetetramine (hexamine) is a solid that can be used as a fuel for camping stoves.




(i) It can be made by reacting aqueous solutions of methanal and ammonia.

$$6CH_2O + 4NH_3 \longrightarrow \underset{\text{hexamine}}{(CH_2)_6N_4} + 6H_2O$$

Calculate the atom economy of this reaction to make hexamine. [2]

Atom economy = ..... %

(ii) Both the high resolution $^{1}H$ NMR and $^{13}C$ NMR spectra of hexamine show only a single peak.

Suggest why these signals are single peaks. [1]

.....

.....

(iii) Hexamine acts as a *tertiary base*.

Explain the meaning of these two terms in this context. [2]

Tertiary .....

.....

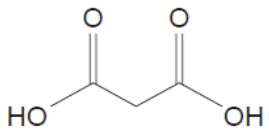
Base .....

.....

Question taken from Eduqas examination paper 841102, October 2021

#18

Malonic acid was first obtained in 1858 by the oxidation of malic acid, which is found in unripe apples.




malonic acid

(a) Give the systematic name of malonic acid. [1]

.....

(b) Both malonic acid and compound **X** have the same molecular formula. Some of the properties of compound **X** are given below.

- Compound **X** does **not** show optical or geometric isomerism.
- The simplified $^{1}$H NMR spectrum of compound **X** shows three separate peaks in the area ratio 1 : 1 : 2.
- A solution, containing 0.704 g of compound **X**, on reaction with excess sodium carbonate, gives 83.0 $cm^3$ of a colourless gas at 25°C and 1 atm pressure.
- Compound **X** does **not** react with 2,4-DNPH.
- Compound **X** decolourises aqueous bromine to form compound **Y** which has a chiral carbon.

Use **all** the information to identify and give the structures of compound **X** and compound **Y**. Show the chiral carbon in compound **Y**. [6]

.....

.....

.....

.....

.....

.....

.....

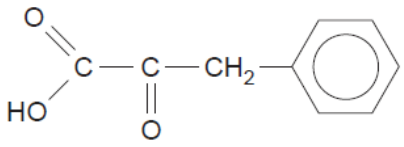
.....

.....

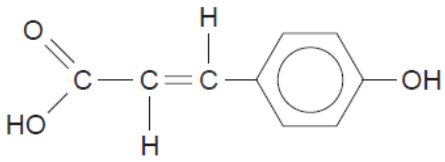
.....

#19

(d) Compound **T** and compound **U** are isomers of formula $C_9H_8O_3$.




compound **T**




compound **U**

(i) State the name of an element that will produce effervescence when added to a solution of either of these two compounds. [1]

.....

(ii) State what is seen when aqueous iron(III) chloride is added to a solution of compound **U**. [1]

.....

(iii) Compound **U** reacts with aqueous bromine to give compound **V**.

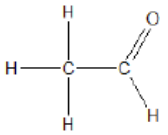
Each molecule of compound **V** contains 9 carbon atoms and 3 oxygen atoms, as well as hydrogen and bromine.

Its mass spectrum shows a molecular ion at m/z 482.

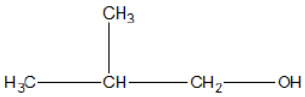
Use this information to deduce a possible structure for compound **V**. Show your reasoning. [4]

# Marking Scheme

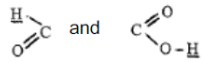
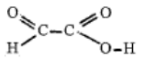
#1

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 10 | (a) | (i) | | $C_2H_5OH + [O] \rightarrow$  $+ H_2O$ | | 1 | | 1 | | |
| | | (ii) | | place acid in flask and add sodium dichromate(VI) until it has dissolved (1)<br><br>(cool mixture) and add ethanol dropwise (shaking between additions) (1)<br><br>set up distillation apparatus (1)<br><br>heat gently until liquid boils over (1) | 4 | | | 4 | | 4 |
| | | (iii) | | add sodium (hydrogen)carbonate (1)<br><br>no effervescence (1)<br><br>do not accept references to pH | 2 | | | 2 | | 2 |
| | (b) | | | award (1) for either of following<br>• ethanol has peak at 50-90 ppm, ethanal does not<br>• ethanal has peak at 190-220 ppm, ethanol does not<br><br>both contain two peaks / one other peak below 40 ppm (1) | | 2 | | 2 | | |
| | (c) | (i) | | bonds broken<br>(5 × 412) + (1 × 348) + (1 × 360) + (1 × 463) + (3 × 496) (1)<br><br>bonds formed<br>(4 × 743) + (6 × 463) (1)<br><br>enthalpy change = 4719 – 5750 = –1031 kJ mol$^{-1}$ (1) | | 3 | | 3 | 2 | |
| | | (ii) | | award (1) for either of following<br>• large quantities of land needed to grow crops for biofuels<br>• growing crops for biofuels needs large quantities of water (and fertilisers) | 1 | | | 1 | | |
| | (d) | | | (due to the —OH group) ethanol forms hydrogen bonds with water (so it is soluble) (1)<br><br>in hexan-1-ol since the carbon chain is longer the effect of the —OH group is now small (so it is insoluble) (1) | 2 | | | 2 | | |
| | | | | **Question 10 total** | **9** | **6** | **0** | **15** | **2** | **6** |

#2

| Question | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|
| | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| (a) | accept any **five** of following for (1) mark each | | | | | | |
| | reacts with potassium dichromate(VI) ⇨ can't be tertiary alcohol (1) | | 1 | | | | |
| | molecular ion peak at m/z 74 ⇨ $M_r$ is 74 (1) | | 1 | | | | |
| | $M_r$ of alkyl chain must be 57 ⇨ molecular formula is $C_4H_{10}O$ (1) | | | 1 | | | |
| | peak at m/z 43 ⇨ $C_3H_7^+$ / peak at m/z 31 ⇨ $CH_2OH^+$ (1) | | 1 | | | | |
| | secondary carbocation ⇨ $(CH_3)_2CH^+$ / branched chain (1) | | | 1 | | | |
| | only three peaks in $^{13}C$ NMR spectrum ⇨ only three carbon environments (1) | | | | 7 | | |
| |  (2) | | | 2 | | | |
| | accept any unambiguous structure showing 2-methylpropan-1-ol | | | | | | |
| | **Question total** | **0** | **3** | **4** | **7** | **0** | **0** |

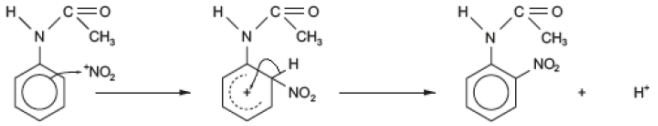
#3

| Question | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|
| | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| (d) | turns UI paper red ⇨ carboxylic acid (1) | | | | | | 1 |
| | two of the three oxygen atoms must be in the acid group (1) | | | | | | |
| | two $^{13}C$ NMR signals ⇨ one carbon atom in an environment other than acid group (1) | | | | | | |
| | $M_r$ is 74 but acid group COOH has $M_r$ 45 ⇨ remainder is 29 must be one carbon, one oxygen and one hydrogen (1) | 2 | 2 | 2 | 6 | | |
| | $^1H$ NMR suggests  (1) | | | | | | |
| | structure of **W** must be  (1) | | | | | | |

#4

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (a) | | | **Indicative content**<br><br>• with sodium hydrogencarbonate<br>methyl methanoate ⇨ no obvious reaction<br>ethanoic acid ⇨ effervescence / $CO_2$ evolved ⇨ shows that it is acidic<br><br>• with universal indicator<br>methyl methanoate ⇨ turns green ⇨ pH7 / neutral / no $H^+$ or $OH^-$ ions present<br>ethanoic acid ⇨ turns orange ⇨ pH<7 / weakly acidic / $H^+$ ions present<br><br>• boiling temperature<br>methyl methanoate – dipole-dipole interactions, lower boiling temperature<br>ethanoic acid – hydrogen bonding, higher boiling temperature<br><br>• $^1H$ NMR<br>methyl methanoate<br>single hydrogen at 9.8 (accept values in range 8-10)<br>methyl hydrogens at 3.3-4.3<br>peak area ratio 3:1 with no splitting<br><br>ethanoic acid<br>single hydrogen at 11.0 (accept values ~11)<br>methyl hydrogens at 2.0-2.5 with no splitting<br><br>**5-6 marks**<br>All essential points described in a reasoned and logical manner<br>*The candidate constructs an articulate, integrated account, which shows sequential reasoning. The answer fully addresses the question with no irrelevant inclusions or significant omissions. The candidate uses scientific conventions and vocabulary appropriately and accurately.*<br><br>**3-4 marks**<br>Basic details of most points described<br>*The candidate constructs an account correctly linking some relevant points showing some reasoning. The answer addresses the question with some omissions. The candidate usually uses scientific conventions and vocabulary appropriately and accurately.*<br><br>**1-2 marks**<br>Attempt at basic description of some points<br>*The candidate makes some relevant points showing limited reasoning. The answer addresses the question with significant omissions. The candidate makes limited use of scientific conventions and vocabulary.*<br><br>**0 marks**<br>*The candidate does not make any attempt or give a relevant answer worthy of credit.* | 2 | 2 | 2 | 6 | | 4 |

## #5

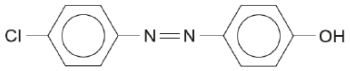
| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (a) | (i) | ethanoyl chloride / $CH_3COCl$ / ethanoic anhydride / $(CH_3CO)_2O$ | 1 | | | 1 | | |
| | | (ii) |  <br>correct curly arrows (1)<br>formula of intermediate (1)<br>formulae of products (1) | | 3 | | 3 | | |
| | | (iii) | any of following for (1)<br>• run the reaction at a higher temperature / above 50 °C<br>• use an excess of the nitrating agent<br>• add the N-phenylethanamide to the nitrating mixture rather than the reverse addition | | | 1 | 1 | | 1 |
| | | (iv) | dissolve in a minimum volume of the hot solvent (1)<br>filter hot if necessary (1)<br>allow to cool (1)<br>filter, (wash) and dry at <180 °C / room temperature / window sill / warm oven (1) | 4 | | | 4 | | 4 |

## #6

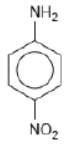
| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | | | for each product award (1) for correct starting compound and reagent(s)<br><br>ignore conditions given in formation of **B** and **G**<br>award (2) for four correct conditions<br>award (1) for two correct conditions | 2 | 4 | 4 | 10 | | 5 |
| **Question total** | | | | **2** | **4** | **4** | **10** | **0** | **5** |

| Starting compound | Product | Reagent(s) | Conditions |
|---|---|---|---|
| **G** | **A** | NaOH | aqueous solvent<br>reflux / heat |
| **H** | | $H_2O$ / steam | 300°C / 60-70 atm<br>$H_3PO_4$ catalyst |
| **H** | **B** | $Br_2$ | liquid or aqueous<br>bromine<br>room temperature |
| **F** | **C** | $HNO_2$ / nitric(III) acid | room temperature |
| **G** | **D** | KCN | ethanol solvent<br>reflux/heat |
| **H** | **E** | $H_2$ | 150°C<br>Ni catalyst |
| **D** | **F** | $LiAlH_4$ | ethoxyethane solvent |
| | | $H_2$ | Pt/Pd/Ni catalyst<br>heat |
| **H** | **G** | HBr | room temperature |
| **G** | **H** | NaOH / KOH | ethanol solvent<br>reflux |
| **A** | | conc $H_2SO_4$ | 170°C |

#7

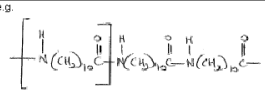
| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (b) | (i) | | the aliphatic C—Cl bond is susceptible to nucleophilic substitution (as it is polarised $C^{\delta+}$—$Cl^{\delta-}$) (1)<br><br>the aryl C—Cl bond is not susceptible to nucleophilic substitution as the C—Cl bond is stronger than the alkyl C—Cl bond (owing to lone pair delocalisation into the benzene ring) (1) | | 2 | | | | |
| | | (ii) | I | 5-10°C | 1 | | | 1 | | 1 |
| | | | II |  | | 1 | | 1 | | |
| | | | III | $8.65 \times 10^{14}$ (2)<br><br>if answer incorrect award (1) for $c = f\lambda$ or $f = \frac{c}{\lambda}$ | 1 | 1 | | 2 | 1 | |

#8

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | *(d)* | (i) | | Sn and conc. HCl | 1 | | | 1 | | 1 |
| | | (ii) | | ethanoyl chloride / ethanoic anhydride / $CH_3COCl$ / $(CH_3CO)_2O$ | 1 | | | 1 | | 1 |
| | | (iii) | |  and $CH_3COO^-Na^+$ (charges unnecessary) | | 1 | | 1 | | |
| | *(e)* | (i) | | stage 1 room temperature / ~20°C / temperatures > 10°C (1)<br><br>stage 2 5-10°C (1) | 2 | | | 2 | | 2 |
| | | (ii) | | $NaCl + H_2O$ | | 1 | | 1 | | |
| | | | | **Question total** | **4** | **2** | **0** | **6** | **0** | **4** |

#9

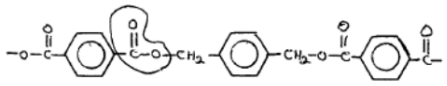
| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 13 | (a) | | | they contain both an acidic and alkaline functional groups | 1 | | | 1 | | |
| | (b) | (i) | | award (1) for any of following<br>• the burette had been rinsed with water and this was not replaced entirely with sodium hydroxide<br>• inadequate shaking<br>• rough titration / overshot end point | 1 | | | 1 | | 1 |
| | | (ii) | | concordant titres chosen - 35.90, 36.00 and 36.10 $cm^3$ (1)<br><br>mean titre = 36.00 $cm^3$ (1)<br><br>n(NaOH) = $\frac{36.00 \times 0.105}{1000}$ = 0.00378 (1)<br><br>1:1 ratio therefore number of moles of the amino acid is also 0.00378<br><br>250 $cm^3$ contain 0.0378 mol (1)<br><br>$M_r$ of the amino acid = $\frac{4.95}{0.0378}$ = 131 (1) | | 5 | | 5 | 1 | |
| | | (iii) | | —CH($NH_2$)COOH '$M_r$' = 74 (1)<br><br>'$M_r$' of chain is 131-74 = 57<br>so must be $C_4H_9$ ecf possible from part (ii)<br><br>formula must be $CH_3CH_2CH_2CH_2CH(NH_2)COOH$ (1) | | | 2 | 2 | | |

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (c) | (i) | | compound T as this is the only one that contains a chiral centre / asymmetric carbon atom | | 1 | | 1 | | |
| | | (ii) | | only compound T would show an N—H stretching frequency at 3300-3500 $cm^{-1}$ | | 1 | | 1 | | |
| | | (iii) | | compound S could only form one dipeptide via its COOH group, as it does not contain an N—H bond | | | 1 | 1 | | |
| | (d) | (i) | | the reaction proceeds via secondary carbocations which are more stable / have lower activation energies<br><br>accept explanation using Markovnikov's rule | | | 1 | 1 | | |
| | | (ii) | I | bromine is more electronegative than carbon / has greater electron attracting power than carbon (so is δ−)<br><br>accept converse argument | 1 | | | 1 | | |
| | | | II | it acts as a base / nucleophile | 1 | | | 1 | | |
| | | (iii) | | e.g.<br>  | | 1 | | 1 | | |
| | | | | Question 13 total | 4 | 8 | 4 | 16 | 2 | 1 |

#10

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (e) | (i) | | $CH_3$ (at 1.66 ppm) is a doublet since the adjacent carbon atom has one hydrogen atom bonded to it (1)<br><br>H (at 5.09 ppm) is a quartet since the adjacent carbon atom has three hydrogen atoms bonded to it (1) | | 2 | | 2 | | |
| | | (ii) | | absorption at 1266 $cm^{-1}$ caused by C—O bond<br>absorption at 1750 $cm^{-1}$ caused by C=O bond<br><br>both needed – accept bonds identified on the structure | | 1 | | 1 | | |
| | | (iii) | | $(CH_3(CH_2)_6COO)_2Sn$ | | | 1 | 1 | | |

## #11

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | *(e)* | (i) | |  | | 1 | | 1 | | |
| | | (ii) | | ring drawn on any ester linkage in repeating section in part (i)<br>e.g. as shown | 1 | | | 1 | | |

## #12

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (b) | | | 20% | 1 | | | 1 | | |

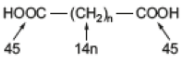
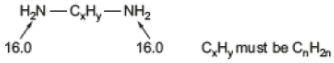
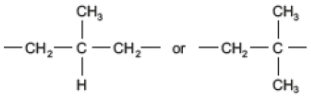
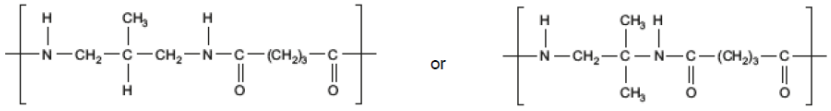
## #13

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (b) | (i) | | 163 | | 1 | | 1 | 1 | |
| | | (ii) | | '$M_r$' → 163 – (12 + 16 + 14 + 1 + 72 + 5) = 43 | | 1 | | 1 | | |
| | | (iii) | | $C_3H_7$ | | 1 | | 1 | | |
| | | (iv) | | $(CH_3)_2CH$ (1)<br><br>award (1) for sensible explanation e.g.<br><br>there are 6 equivalent protons<br>protons are in 6:1 ratio<br>there are (only) two proton environments | | 1 | 1 | 2 | | |

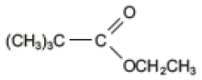
## #14

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (b) | (i) | | nucleophilic substitution | | 1 | | 1 | | |
| | | (ii) | | nitrogen acts as a base / has a lone pair which reacts with $H^+$ | | | 1 | 1 | | |
| | | (iii) | I | KCN / potassium cyanide | 1 | | | 1 | | 1 |
| | | | II | the value/intensity of the absorption at 2100-2250 $cm^{-1}$ decreases because the C≡N bond is replaced (by a C—N bond) during the reaction | 1 | | | 1 | | |
| | | | III | reduction / addition | 1 | | | 1 | | |

#15

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (f) | | | **Indicative content**<br>• **K** is a dicarboxylic acid – 1 mol of the acid reacts with 2 mol of NaOH<br>• number of moles of NaOH = 0.500 × 37.55 / 1000 = 0.0188<br>• number of moles of **K** is 0.00939<br>• $M_r$ of the acid = 1.24/0.00939 = 132<br>•  <br><br>132 – 90 = 42 14n = 42 n = 3<br>• formula of acid **K** is $HOOC(CH_2)_3COOH$<br><br>• 2 mol of nitrogen (48000 $cm^3$) from 1 mol of **L**<br>• 278 $cm^3$ from 0.500g **L** ⇒ 49000 $cm^3$ from 0.500 × 49000/278 = 88.1 $M_r$ **L** is 88<br>•  <br><br>• hence $C_4H_8$<br>• $C_4H_8$ can be arranged —$CH_2$—$CH_2$—$CH_2$—$CH_2$—<br>• this has 2 different carbon-containing environments in its $^{13}C$ NMR spectrum<br>• alternatively it can be arranged<br>•  <br><br>• these have 3 different carbon-containing environments (as stated in the question) **L** must be $H_2N$—$CH_2$—$CH(CH_3)$—$CH_2$—$NH_2$ or $H_2N$—$CH_2$—$C(CH_3)_2$—$NH_2$<br>• the repeating section of the polyamide **J** is<br>  <br> | | | | | | |
| | | | | **5-6 marks**<br>The response shows unambiguous correct formulae for **J**, **K** and **L**.<br>*The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.*<br><br>**3-4 marks**<br>The response shows some unambiguous correct formulae for **J**, **K** and **L**.<br>*The candidate constructs a coherent account including many of the key elements of the indicative content. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.*<br><br>**1-2 marks**<br>The response shows a less clear attempt at deriving the formulae of **J**, **K** and **L**.<br>*The candidate attempts to link at least two relevant points from the indicative material. Coherence is limited by omission and/or inclusion of irrelevant materials. There is some evidence of appropriate use of scientific conventions and vocabulary.*<br><br>**0 marks**<br>*The candidate does not make any attempt or give an answer worthy of credit.* | | | | | | |

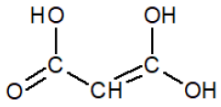
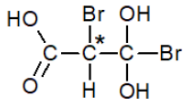
#16

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | (e) | | | award up to (2) marks for identification of **R** as an ester with clear reasoning<br><br>• **R** contains only carbon, hydrogen and oxygen – it must be either an alcohol, an ester or a carboxylic acid (1)<br>• **R** contains a C=O group so it cannot be an alcohol and it is neutral therefore cannot therefore be a carboxylic acid (1)<br><br>award up to (4) marks for identifying **S** as $(CH_3)_3C—COOH$<br><br>• **S** is product of ester hydrolysis and weakly acidic – must be a carboxylic acid (1)<br>• $^1H$ NMR signal with the relative peak area of 1 must be that of the carboxylic acid group proton at around 11δ (1)<br>• the other 9 protons must be identical since the signal is not split – this suggests a $(CH_3)_3$ group (1)<br>• $^{13}C$ spectrum shows three different carbon environments – one carbon must be in the —COOH group and the other two are in a $(CH_3)_3C—$ group (1)<br><br>award up to (4) marks for identifying **T** as $CH_3CH_2OH$<br><br>• **T** must be an alcohol (1)<br>• $^{13}C$ NMR of **T** suggests ethanol and this is confirmed by $^1H$ NMR spectrum showing three signals of relative peak area 1:2:3 (1)<br>• signal at 5.5δ corresponds to O—H proton, signal centred on ~4.5δ corresponds to the $CH_2$ protons and that at 1.4δ corresponds to the $CH_3$ protons (1)<br>• splitting pattern further confirms ethanol with —$CH_2$ protons split by adjacent —$CH_3$ group giving quartet; —$CH_3$ protons split by adjacent —$CH_2$ giving triplet (1)<br>• (displayed) formula of **R** is<br><br>  <br>(1) | 5 | 6 | 11 | | 3 |

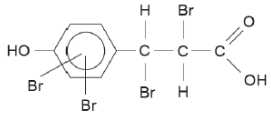
#17

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| | *(a)* | (i) | | $\frac{140}{(6 \times 30) + (4 \times 17)} \times 100 = 56$<br><br>award (2) for correct answer<br><br>if answer incorrect award (1) for three correct $M_r$ values<br><br>$M_r[(CH_2)_6N] = 140$<br>$M_r(CH_2O) = 30$<br>$M_r(NH_3) = 17$ | | 2 | | 2 | 1 | |
| | | (ii) | | all carbon atoms are in same environment and all hydrogen protons are in the same environment | | | 1 | 1 | | |
| | | (iii) | | tertiary - nitrogen atom bonded directly to three carbon atoms (1)<br><br>base - nitrogen atom has lone pair (which it can donate) (1) | 1 | | 1 | 2 | | |

#18

| Question | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|
| | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| (a) | propanedioic acid<br><br>accept 1,3-propanedioic acid | | 1 | | 1 | | |
| (b) | award credit for **any** of the following inferences/conclusions drawn from the information given<br><br>1. no reaction with 2,4-DNPH ⇨ no carbonyl group<br>2. aqueous bromine decolourised ⇨ **X** contains a C=C bond<br>3. reacts with sodium carbonate to form colourless gas<br>⇨ carboxylic acid group present<br>4. $n(CO_2) = \frac{83.0 \times 10^{-3}}{24.5} = 0.00339$ mol<br>$n(\mathbf{X}) = \frac{0.704}{104.04} = 0.00677$ mol<br>5. ratio $CO_2$ : **X** ⇨ 1:2 therefore one carboxylic acid group present<br>6. **X** does not show optical isomerism because none of the carbon atoms is bonded to four different groups / there is no chiral carbon<br>7. **X** does not have geometric isomerism because one carbon of the C=C group has two —OH groups attached<br>8. $^1$H NMR spectrum of compound **X** would show three peaks<br>⇨ carboxylic —OH (area 1); —CH=C (area 1);<br>alcohol —OH (area 2)<br><br>award (4) for points 1-5 **and** any **two** others<br>award (3) for points 1-5<br>award (2) for any **five** points<br>award (1) for any **three** points<br><br>award (1) for each correct structure<br><br>compound **X**<br>  <br><br>compound **Y**<br>  chiral carbon **must** be identified | 2 | 2 | 2 | 6 | 2 | 4 |
| | **Question total** | **2** | **3** | **2** | **7** | **2** | **4** |

#19

| Question | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|
| | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| (d) (i) | magnesium / zinc | | 1 | | 1 | | 1 |
| (ii) | purple coloration / solution | 1 | | | 1 | | 1 |
| (iii) | award (1) for reference to mass of 9 carbon atoms and 3 oxygen atoms in working e.g. 108 + 48 = 156<br><br>award (1) for reference to 4 bromine atoms in working<br><br>award (1) for reference to 6 hydrogen atoms in working<br><br>(2nd and 3rd marks can be awarded for molecular formula $C_9H_6Br_4O_3$)<br>  <br>(1) | | | 4 | 4 | 2 | |