

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname *StemUp Model Solution*

Forename(s)

Candidate signature

INTERNATIONAL A-LEVEL CHEMISTRY (9620)

Unit 4: Organic 2 and Physical 2

Friday 7 June 2019

07:00 GMT

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert
- 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. Use pencil only for drawing.
- 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 blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- 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 80.

For Examiner's Use	
Question	Mark
1	
2	
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5	
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7	
8	
TOTAL	



J U N 1 9 C H 0 4 0 1

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

Do not write
outside the
box

0 1

This question is about amines.

0 1 . 1

Write an ionic equation for the reaction between propylamine and hydrochloric acid.

[1 mark]



0 1 . 2

Explain why propylamine is a stronger base than ammonia.

[2 marks]

The propyl (alkyl) group is electron-releasing (positive inductive effect), unlike H in ammonia.

This increases the electron density on the N, so the lone pair on N is more available to accept a proton (H⁺).

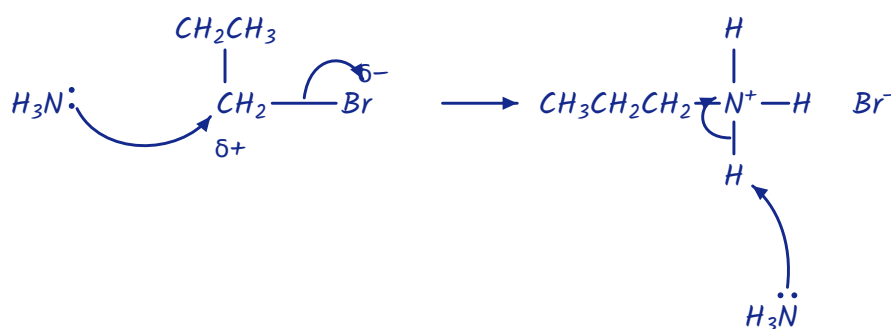
0 1 . 3

Name and outline a mechanism for the reaction of ammonia with 1-bromopropane to form propylamine.

[5 marks]

Name of mechanism nucleophilic substitution

Mechanism



0 1 . 4

Explain why the reaction in Question 01.3 may give a low yield of propylamine.

[1 mark]

*Propylamine is also a nucleophile, so it reacts further with
1-bromopropane, forming secondary and tertiary amines.*

0 1 . 5

Propylamine reacts with bromoethane, under specific conditions, to give a compound with the formula $C_9H_{22}NBr$

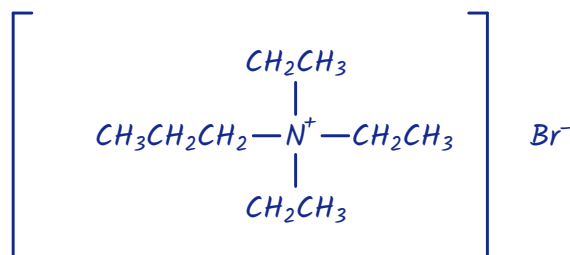
Draw the structure of the compound with the formula $C_9H_{22}NBr$

Identify this type of compound.

Give a use for this type of compound.

[3 marks]

Structure



Type of compound quaternary ammonium salt

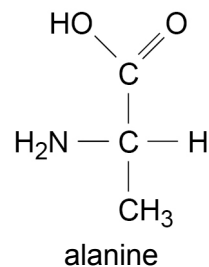
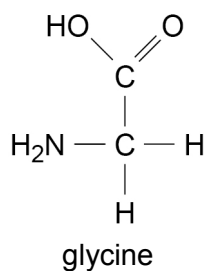
Use cationic surfactant (fabric softener / detergent)



0 2

This question is about amino acids and peptides.

The structures of two amino acids, glycine and alanine, are shown.



0 2 . 1

Use IUPAC rules to name alanine.

[1 mark]

2-aminopropanoic acid

0 2 . 2

State why glycine does **not** show optical activity.

[1 mark]

Glycine has no chiral carbon atom: its central carbon is bonded to two H atoms, so no carbon has four different groups attached.

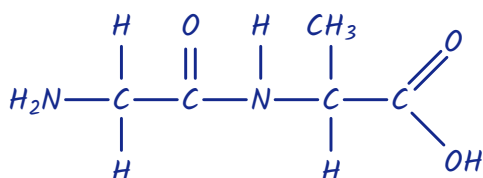
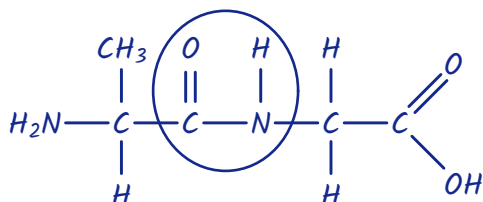


0 2 . 3

Draw the structure of each of the two dipeptides that are formed when glycine reacts with alanine.

Circle the peptide link in **one** of your structures.

[3 marks]

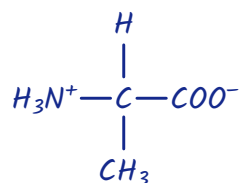


0 2 . 4

Draw the structure of the zwitterion of alanine.
Explain why alanine has a high melting point.

[2 marks]

Structure



Explanation There is strong electrostatic attraction between the
oppositely charged ions (NH_3^+ and COO^-) of neighbouring zwitterions, so
a lot of energy is needed to overcome these ionic bonds.

Turn over ►



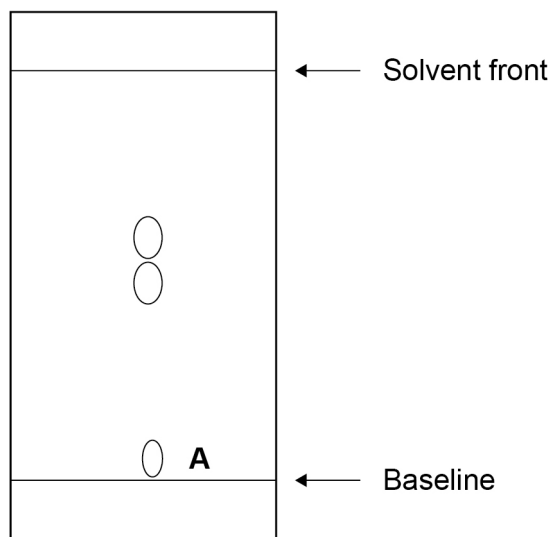
0 2 . 5

A peptide is known to contain **four** different amino acids.

In an experiment a student heats the peptide with acid to help hydrolyse it.
The student analyses the resulting mixture by thin-layer chromatography (TLC).

Figure 1 shows a diagram of the chromatogram that the student obtains.

Figure 1



The spot just above the baseline, labelled **A**, contains a mixture of substances.
This mixture cannot be separated using this method.

Identify a developing agent that can be used to locate the amino acids on the chromatogram.

Suggest a possible reason why the R_f value of the compounds in spot **A** is low.

[2 marks]

Identity of developing agent ninhydrin (or UV light)

Reason for low R_f value larger molecules (peptides) that are much less soluble in the solvent and strongly attracted to the stationary phase

0 2 . 6

Suggest **two** reasons why there are only three spots on the chromatogram.

[2 marks]

Reason 1 Some of the peptide is unhydrolysed or only partially hydrolysed (dipeptides / tripeptides).

Reason 2 Two of the amino acids have the same solubility (same R_f), so their spots overlap.



R_f values of some amino acids are given in **Table 1**

Table 1

Amino acid	glycine	methionine	phenylalanine	serine	tyrosine
R_f value	0.26	0.59	0.75	0.23	0.48

0 2 . 7 Identify the **two** amino acids in the hydrolysed mixture that can be identified from the chromatogram.

Tick (✓) **two** boxes.

[1 mark]

Glycine

☐

Methionine

☒

Phenylalanine

☐

Serine

☐

Tyrosine

☒

0 2 . 8 State why the structure of a peptide **cannot** be determined from a chromatogram, even if the identity of all the amino acids is known.

[1 mark]

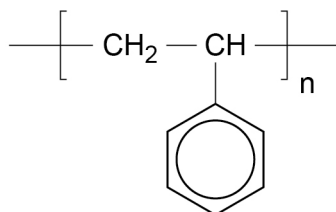
Chromatography only shows which amino acids are present; it does not show the order (sequence) in which they are joined in the peptide.



0 3

This question is about polymers.

The structure of polymer **A** is shown.



0 3 . 1

State the type of polymerisation used to make **A**.

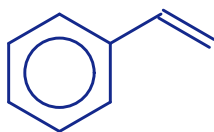
[1 mark]

addition (polymerisation)

0 3 . 2

Draw the skeletal formula of the monomer used to make **A**.

[1 mark]



0 3 . 3

Explain why **A** is not biodegradable.

[2 marks]

The polymer backbone is made of strong, non-polar C–C (and C–H) bonds.

So it cannot be hydrolysed or attacked by acids, alkalis or nucleophiles, and microorganisms cannot break it down.



0 3 . 4

After use, some materials made of polymers can be recycled.

State **one** disadvantage of recycling materials made of polymers.

[1 mark]

*The waste polymers must be collected and sorted into different types,
which is labour-intensive, and transport costs are high.*

0 3 . 5

After use, some materials made of polymers cannot be recycled.
These materials can be disposed of by burning.

State **one** disadvantage of burning as a method of disposing of materials made of polymers.

[1 mark]

*Toxic gases such as carbon monoxide are produced (and CO₂, a
greenhouse gas that contributes to global warming).*

6

Turn over for the next question

Turn over ►



0 4

This question is about structure determination.

Use Tables **A**, **B** and **C** on the Data Sheet to help answer Questions **04.1** to **04.4**

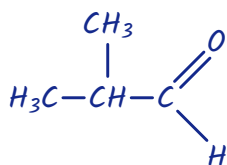
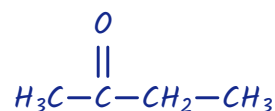
0 4 . 1

Isomers **P** and **Q** have the molecular formula C_4H_8O

When warmed with Tollens' reagent:

P gives a silver mirror**Q** does not give a silver mirror

In their infrared spectra:

P and **Q** both have a strong absorption in the $1700-1725\text{ cm}^{-1}$ regionIn their ^{13}C NMR spectra:**P** has three peaks**Q** has four peaksDeduce the structure of **P** and the structure of **Q**.**[2 marks]****P****Q**

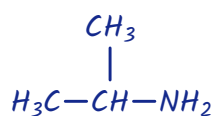
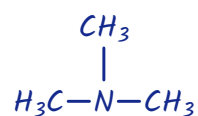
0 4 . 2

Isomers **R** and **S** have the molecular formula $\text{C}_3\text{H}_9\text{N}$

In their infrared spectra:

R has absorptions in the $3350\text{--}3450\text{ cm}^{-1}$ region**S** has no absorptions at wavenumbers greater than 3100 cm^{-1} In their ^1H NMR spectra:**R** has three peaks**S** has only one peakDeduce the structure of **R** and the structure of **S**.

[2 marks]

R**S**

Question 4 continues on the next page

Turn over ►



0	4	.	3
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Isomers **T** and **U** have the molecular formula C_6H_{12}

In their infrared spectra:

T has an absorption at 1650 cm^{-1}

U has no absorptions between 1500 and 2900 cm^{-1}

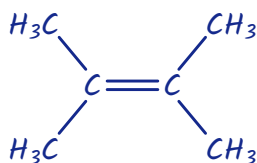
In their ^1H NMR spectra:

T and **U** both have only one peak

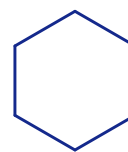
Deduce the structure of **T** and the structure of **U**.

[2 marks]

T



U



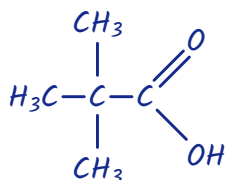
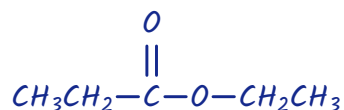
0 4 . 4

Isomers **V** and **W** have the molecular formula $C_5H_{10}O_2$

In their infrared spectra:

V and **W** both have strong absorptions in the $1700-1750\text{ cm}^{-1}$ regionIn their ^1H NMR spectrum:**V** has two peaks (both singlets) with integration ratio 9:1**W** has four peaks (two triplets and two quartets) with integration ratio 3:3:2:2

With aqueous sodium carbonate:

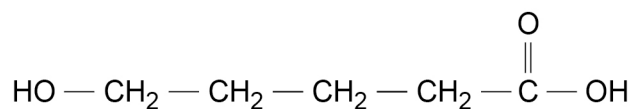
V effervesces**W** does not effervesceDeduce the structure of **V** and the structure of **W**.**[2 marks]****V****W**

Turn over for the next question

Turn over ►



0 5

The structure of compound **X** is shown.

0 5 . 1

Use IUPAC rules to name **X**.

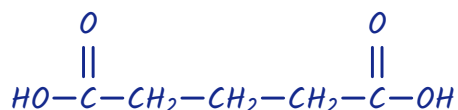
[1 mark]

5-hydroxypentanoic acid

0 5 . 2

Draw the structure of the compound formed when **X** is heated under reflux with an excess of acidified potassium dichromate(VI).

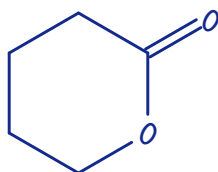
[1 mark]



0 5 . 3

When **X** is warmed with a few drops of concentrated sulfuric acid, a cyclic compound with the molecular formula $\text{C}_5\text{H}_8\text{O}_2$ is formed.Draw the skeletal formula of the compound with molecular formula $\text{C}_5\text{H}_8\text{O}_2$ formed in this reaction.

[1 mark]

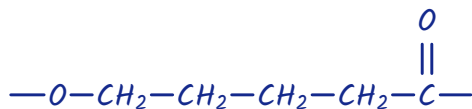


0 5 . 4

X forms a polymer by reaction with itself, in the presence of a catalyst.

Draw **one** repeating unit of this polymer.

[1 mark]



4

0 6

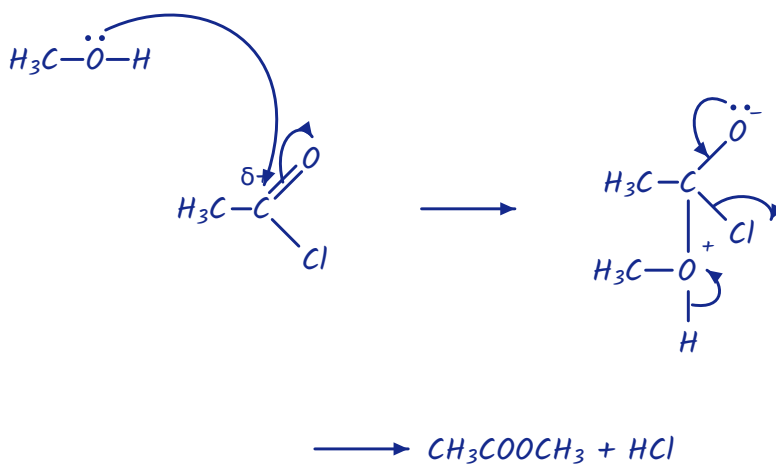
Alcohols react with acyl chlorides.

Name and outline a mechanism for the reaction of methanol with ethanoyl chloride.

[5 marks]

Name of mechanism (nucleophilic) addition-elimination

Mechanism



5

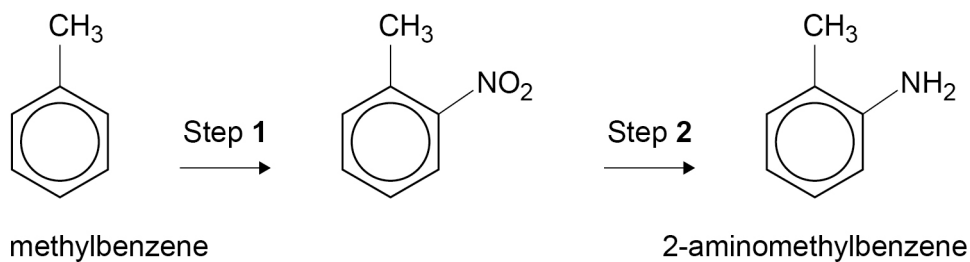
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0 7

A two-step preparation of 2-aminomethylbenzene starting from methylbenzene is shown.



0 7 . 1

In Step 1, methylbenzene undergoes an electrophilic substitution reaction.

Identify the reagents needed for this reaction.

Write an equation to show the formation of the electrophile.

Outline the mechanism for the reaction in Step 1 of methylbenzene with this electrophile.

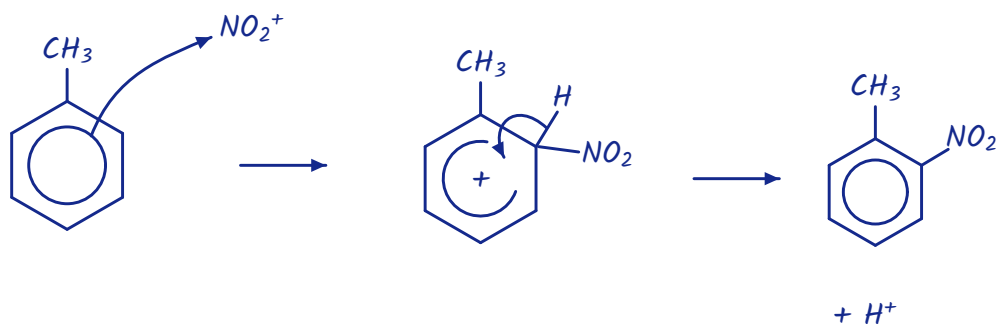
[6 marks]

Reagents concentrated nitric acid (HNO_3) and concentrated sulfuric acid (H_2SO_4)

Equation



Mechanism



0 7 . 2

Give the structure of **one other** organic product formed in Step 1

[1 mark]



0 7 . 3

In this two-step preparation 10.0 cm³ of methylbenzene ($M_r = 92.0$) were used.

4.42 g of 2-aminomethylbenzene were obtained.

Calculate the percentage yield in this preparation.

The density of methylbenzene = 0.870 g cm⁻³

[3 marks]

$$\text{mass of methylbenzene} = 10.0 \times 0.870 = 8.70 \text{ g}$$

$$n(\text{methylbenzene}) = 8.70 \div 92.0 = 0.0946 \text{ mol}$$

$$M_r \text{ of 2-aminomethylbenzene (C}_7\text{H}_9\text{N)} = 107.0$$

$$\text{maximum mass} = 0.0946 \times 107.0 = 10.12 \text{ g}$$

$$\% \text{ yield} = 4.42 \div 10.12 \times 100 = 43.7\%$$

% yield 43.7

0 7 . 4

Explain why methylbenzene does **not** react easily with nucleophiles such as ammonia.

[2 marks]

The delocalised π electrons make the benzene ring electron-rich (a region of high electron density).

So the ring repels nucleophiles such as NH_3 , which are electron-pair donors.



0 8

This question is about acids and bases.

0 8 . 1

State what is meant by a Brønsted–Lowry acid.

[1 mark]

a proton (H^+) donor

0 8 . 2

Hydrochloric acid is a strong acid.

10.0 cm³ of 5.00 mol dm⁻³ hydrochloric acid are diluted with distilled water to form 250 cm³ of solution.

Calculate the pH of the solution formed.
Give your answer to 2 decimal places.

[3 marks]

$$n(HCl) = 10.0 \times 5.00 \div 1000 = 0.0500 \text{ mol}$$

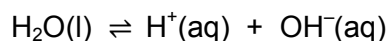
$$[HCl] = [H^+] = 0.0500 \times 1000 \div 250 = 0.200 \text{ mol dm}^{-3}$$

$$pH = -\log(0.200) = 0.70$$

pH 0.70

0 8 . 3

Water dissociates as shown.



Give an expression for the ionic product of water, K_w
State the effect of increasing temperature on the value of K_w
Explain your answer.

[4 marks]

$$K_w = [H^+][OH^-]$$

Effect of increasing temperature K_w increases

Explanation The dissociation of water is endothermic, so increasing the temperature shifts the equilibrium to the right (more water dissociates), increasing $[H^+]$ and $[OH^-]$.



08.4

Calculate the pH of $0.125 \text{ mol dm}^{-3}$ aqueous sodium hydroxide at 298 K
Give your answer to 2 decimal places.

The ionic product of water, $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K

[2 marks]

$$[H^+] = K_w \div [OH^-] = 1.00 \times 10^{-14} \div 0.125 = 8.00 \times 10^{-14} \text{ mol dm}^{-3}$$

$$pH = -\log(8.00 \times 10^{-14}) = 13.10$$

pH 13.10

08.5

Propanoic acid is a weak acid.

An aqueous solution of propanoic acid has a pH of 2.85 at 298 K

Calculate the concentration, in mol dm^{-3} , of this solution.
Give your answer to 3 significant figures.

The acid dissociation constant of propanoic acid, $K_a = 1.35 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K

[3 marks]

$$[H^+] = 10^{-2.85} = 1.41 \times 10^{-3} \text{ mol dm}^{-3}$$

$$K_a = [H^+][CH_3CH_2COO^-] \div [CH_3CH_2COOH] = [H^+]^2 \div [HA]$$

$$[HA] = [H^+]^2 \div K_a = (1.41 \times 10^{-3})^2 \div 1.35 \times 10^{-5}$$

$$[HA] = 0.148 \text{ mol dm}^{-3}$$

Concentration 0.148 mol dm^{-3}

Question 8 continues on the next page

Turn over ►



08.6

A buffer solution is formed when

10.0 cm³ of 0.210 mol dm⁻³ aqueous sodium hydroxide are added to
25.0 cm³ of 0.250 mol dm⁻³ aqueous propanoic acid.

Calculate the pH of the buffer solution at 298 K
Give your answer to 2 decimal places.

The acid dissociation constant of propanoic acid, $K_a = 1.35 \times 10^{-5}$ mol dm⁻³ at 298 K

[5 marks]

$$n(\text{HA}) = 0.250 \times 25.0 \div 1000 = 6.25 \times 10^{-3} \text{ mol}$$

$$n(\text{NaOH}) = 0.210 \times 10.0 \div 1000 = 2.10 \times 10^{-3} \text{ mol} = n(\text{A}^-) \text{ formed}$$

$$n(\text{HA}) \text{ left} = 6.25 \times 10^{-3} - 2.10 \times 10^{-3} = 4.15 \times 10^{-3} \text{ mol}$$

$$[\text{H}^+] = K_a \times n(\text{HA}) \div n(\text{A}^-) = 1.35 \times 10^{-5} \times 4.15 \times 10^{-3} \div 2.10 \times 10^{-3}$$

$$[\text{H}^+] = 2.67 \times 10^{-5} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log(2.67 \times 10^{-5}) = 4.57$$

pH 4.57

08.7

A small amount of hydrochloric acid is added to the buffer solution in Question 08.6

Explain why the pH of the buffer solution stays almost constant when the
hydrochloric acid is added.

[2 marks]

Propanoate ions (A^-) remove the added H^+ ions (equilibrium shifts
left):



$[\text{HA}]/[\text{A}^-]$ hardly changes, so $[\text{H}^+]$ stays almost constant.

END OF QUESTIONS

20



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