



Rewarding Learning

ADVANCED
General Certificate of Education
2024

Centre Number

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Candidate Number

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Chemistry

StemUp Model Solution

Assessment Unit A2 1

assessing

Further Physical and
Organic Chemistry



[ACH14]

ACH14

TUESDAY 28 MAY, MORNING

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

Answer **all sixteen** questions in **Sections A and B**.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen or a pencil.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 110.

Quality of written communication will be assessed in Questions **14(a)** and **16(c)(iii)**.

The figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

A Periodic Table of Elements, containing some data, is included with this question paper.

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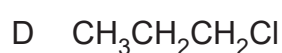
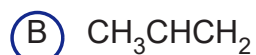
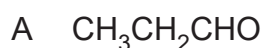


Section A

For each of the following questions, only **one** of the lettered responses (A–D) is correct.

Select the correct response for each question and write the appropriate letter in the space provided.

1 Which one of the following compounds does **not** react with nucleophiles?



Answer B [1]

2 In which one of the following reaction mixtures does a redox reaction occur?

A ethanal and hydrogen cyanide

☒ B ethanal and Tollens' reagent

C ethanoic acid and sodium hydroxide

D ethanoyl chloride and ethanol

Answer B [1]



- 3 The boiling point of ethyl ethanoate is 77°C . The boiling point of pentyl hexanoate is 226°C . Which one of the following is responsible for the higher boiling point of pentyl hexanoate?

A covalent bonds
B hydrogen bonds
C permanent dipole-dipole attractions
☒ D van der Waals' forces

Answer D [1]

- 4 Propanone reacts with 2,4-dinitrophenylhydrazine to form a 2,4-dinitrophenylhydrazone. Which one of the following is the molecular formula of the 2,4-dinitrophenylhydrazone?

A $\text{C}_9\text{H}_8\text{N}_4\text{O}_4$
B $\text{C}_9\text{H}_{10}\text{N}_3\text{O}_4$
☒ C $\text{C}_9\text{H}_{10}\text{N}_4\text{O}_4$
D $\text{C}_9\text{H}_{11}\text{N}_4\text{O}_4$

Answer C [1]

- 5 Which one of the following is correct for the entropy change and enthalpy change for a reaction which is feasible at all temperatures?

	ΔS	ΔH
A	negative	negative
B	negative	positive
☒ C	positive	negative
D	positive	positive

Answer C [1]

[Turn over]



6 Which one of the following statements is **not** correct?

- ☒ A a benzene molecule contains 24 electrons
- ☐ B all carbon–carbon bonds in benzene are the same length
- ☐ C benzene undergoes substitution reactions
- ☐ D chlorine reacts more slowly with benzene than it does with ethene

Answer A [1]

7 A pure sample of a fat is known to be the triester of glycerol and a fatty acid. 0.30 mol of the fat requires 21.6 dm³ of hydrogen at room temperature for complete hydrogenation. Which one of the following is the formula of the fatty acid in the fat?

- ☐ A C₁₅H₃₁COOH
- ☐ B C₁₇H₃₁COOH
- ☒ C C₁₇H₃₃COOH
- ☐ D C₁₇H₃₅COOH

Answer C [1]

8 Propanone can be reduced to form an alcohol. Which one of the following is an isomer of the alcohol formed, which belongs to a different homologous series?

- ☐ A CH₃CH₂CH₂OH
- ☐ B CH₃CH₂CHO
- ☒ C CH₃OCH₂CH₃
- ☐ D CH₃CH(OH)CH₃

Answer C [1]



9 Which one of the following does **not** contain an asymmetric centre?

- ☒ A $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$
B $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$
C $\text{CH}_3\text{CHClCH}_2\text{CH}_3$
D $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{CH}_3$

Answer A [1]

10 The rate of decomposition of ethanal at 500°C is given by the equation:

$$\text{rate} = k [\text{ethanal}]^2$$

Which one of the following shows the units for k ?

- A s^{-1}
B $\text{mol dm}^{-3} \text{s}^{-1}$
☒ C $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$
D $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$

Answer C [1]

[Turn over]

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Section B

Answer **all six** questions in this section

11 A cleaning solution is a solution of sodium hydroxide.

(a) A sample of 25.0 cm^3 of the cleaning solution was titrated using 0.525 mol dm^{-3} ethanoic acid. The mean titre was found to be 17.2 cm^3 .

(i) Calculate the concentration, in mol dm^{-3} , of sodium hydroxide in the cleaning solution. Give your answer to 3 significant figures.

$$\text{moles CH}_3\text{COOH} = 17.2 \times 0.525 \div 1000 = 9.03 \times 10^{-3} \text{ mol}$$

$$\text{NaOH reacts } 1 : 1, \text{ so moles NaOH in } 25.0 \text{ cm}^3 = 9.03 \times 10^{-3} \text{ mol}$$

$$\begin{aligned} [\text{NaOH}] &= 9.03 \times 10^{-3} \times 1000 \div 25.0 = 9.03 \times 10^{-3} \times 40 \\ &= 0.361 \text{ mol dm}^{-3} \end{aligned}$$

Answer 0.361 mol dm^{-3} [2]

(ii) Calculate the pH of the cleaning solution at 25°C . Give your answer to 2 decimal places.

$$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6} \text{ at } 25^\circ\text{C}.$$

$$[\text{OH}^-] = 0.361 \text{ mol dm}^{-3}$$

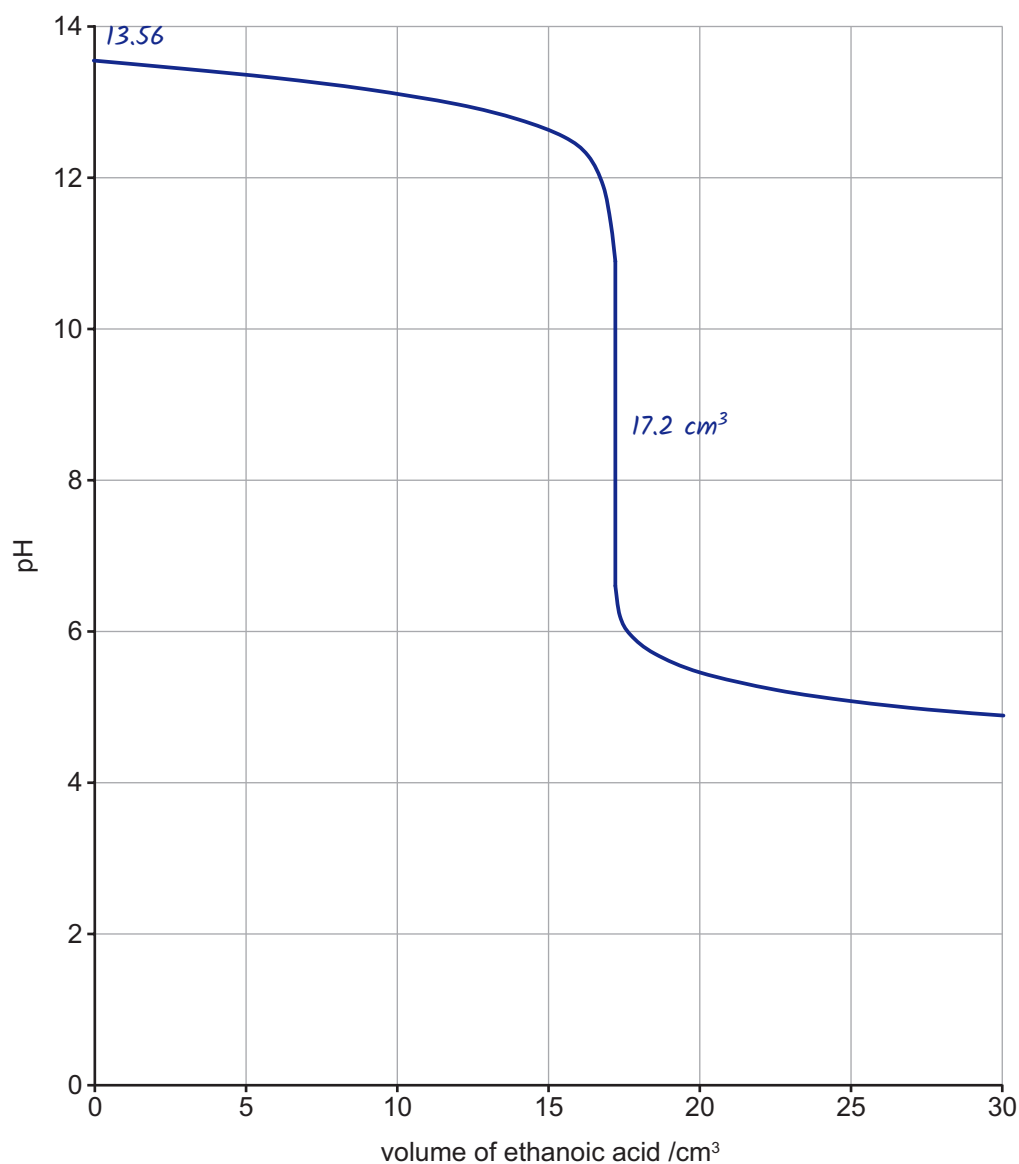
$$[\text{H}^+] = K_w \div [\text{OH}^-] = 1.00 \times 10^{-14} \div 0.361 = 2.77 \times 10^{-14} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log_{10}(2.77 \times 10^{-14}) = 13.56$$

Answer 13.56 [2]



(iii) Using your answer to (a)(ii) and the information given in the question, sketch the titration curve for this titration on the axes below.



[3]

(iv) Name an indicator for this titration and explain why it is a suitable choice.

Phenolphthalein.

This is a weak acid and strong base titration: phenolphthalein

changes colour (pH 8.3 to 10) within the pH range of the vertical
region of the titration curve.

[2]

[Turn over]

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(b) 25.0 cm³ of the cleaning solution may also be titrated using 0.525 mol dm⁻³ sulfuric acid.

(i) Describe two ways in which the titration curve would be different to the one in (a)(iii).

1. The vertical region occurs at a lower volume of acid (about 8.6 cm³), as H₂SO₄ is diprotic.
2. The vertical region extends lower, from about pH 11 to pH 3, as sulfuric acid is a strong acid. [2]

(ii) 20.0 cm³ of the 0.525 mol dm⁻³ sulfuric acid were placed in a volumetric flask and the volume made up to 250.0 cm³ using deionised water. Calculate the pH of the resulting solution. Give your answer to 2 decimal places.

$$\text{moles H}_2\text{SO}_4 = 20.0 \times 0.525 \div 1000 = 0.0105 \text{ mol}$$

$$\text{H}_2\text{SO}_4 \text{ is diprotic: moles H}^+ = 2 \times 0.0105 = 0.0210 \text{ mol}$$

$$\text{new volume} = 250.0 \text{ cm}^3$$

$$[\text{H}^+] = 0.0210 \times 1000 \div 250.0 = 0.0210 \times 4 = 0.0840 \text{ mol dm}^{-3}$$

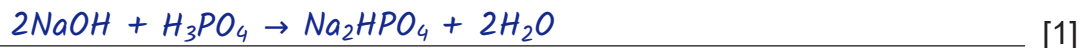
$$\text{pH} = -\log_{10}(0.0840) = 1.08$$

Answer 1.08 [3]

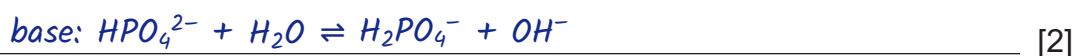


(c) Sodium hydroxide reacts with phosphoric acid, H_3PO_4 , to form salts including sodium hydrogenphosphate, Na_2HPO_4 . The hydrogenphosphate ion can act as a Brønsted–Lowry acid and as a Brønsted–Lowry base.

(i) Write an equation for the reaction between sodium hydroxide and phosphoric acid to form sodium hydrogenphosphate.



(ii) Show, using equations, how the hydrogenphosphate ion can act as a Brønsted–Lowry acid and as a Brønsted–Lowry base in aqueous solution.



(iii) Another salt of phosphoric acid is sodium phosphate, Na_3PO_4 . Explain why a solution of sodium phosphate is alkaline.

It is the salt of a strong base and a weak acid: phosphate ions

react with water to form hydroxide ions, $\text{PO}_4^{3-} + \text{H}_2\text{O} \rightleftharpoons \text{HPO}_4^{2-}$

+ OH^- [1]

[Turn over]

14027.05R



- 12 Butanoic acid and 2-hydroxypropanoic acid are weak monobasic acids. The table below summarises some properties of both acids.

Acid	Formula	Boiling point /°C	Acid dissociation constant (K_a) at 25 °C /mol dm ⁻³
butanoic acid	CH ₃ CH ₂ CH ₂ COOH	163.5	1.51×10^{-5}
2-hydroxypropanoic acid	CH ₃ CH(OH)COOH	122.0	1.38×10^{-4}

- (a) (i) Define the term **monobasic acid**.

An acid which donates one proton (H⁺) per molecule.

[1]

- (ii) Suggest why the boiling point of butanoic acid is higher than the boiling point of 2-hydroxypropanoic acid.

Butanoic acid has a straight chain, so there are stronger (more) van der Waals forces between its molecules (greater surface contact).

[2]

- (iii) On mixing 2-hydroxypropanoic acid with butanoic acid, an acid-base equilibrium is set up. Give the formula for the base and its conjugate acid for the forward reaction in this equilibrium.

base: *CH₃CH₂CH₂COOH*

conjugate acid: *CH₃CH₂CH₂COOH₂⁺*

[2]



- (iv) Calculate the mass of 2-hydroxypropanoic acid required to produce a 250.0 cm³ solution with a pH of 2.40. Give your answer to 3 significant figures.

$$[H^+] = 10^{-2.40} = 3.98 \times 10^{-3} \text{ mol dm}^{-3}$$

$$K_a = [H^+]^2 \div [\text{acid}], \text{ so } [\text{acid}] = [H^+]^2 \div K_a$$

$$[\text{acid}] = \frac{(3.98 \times 10^{-3})^2}{1.38 \times 10^{-4}} = 0.1148 \text{ mol dm}^{-3}$$

$$\text{moles} = 0.1148 \times 250.0 \div 1000 = 0.0287 \text{ mol}$$

$$M_r \text{ of } CH_3CH(OH)COOH = 3(12) + 6(1) + 3(16) = 90$$

$$\text{mass} = 0.0287 \times 90 = 2.58 \text{ g}$$

Answer 2.58 g [4]



(b) 2-hydroxypropanoic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$, is also known as lactic acid. Industrially, lactic acid is produced by the addition of hydrogen cyanide to ethanal to form a hydroxynitrile followed by hydrolysis of the hydroxynitrile.

- (i) Write the equation for the reaction of ethanal with hydrogen cyanide to form the hydroxynitrile.



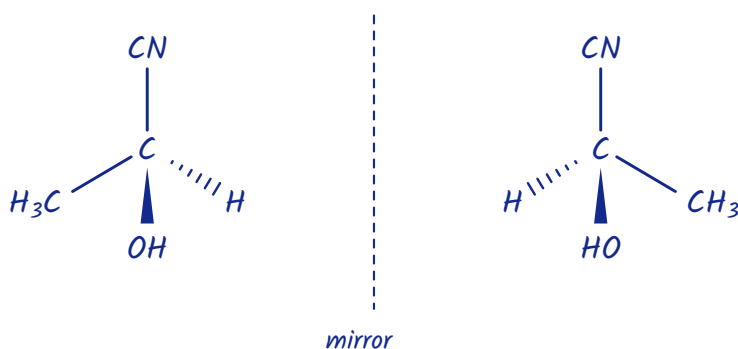
- (ii) Suggest the IUPAC name for the hydroxynitrile formed in the reaction of ethanal and hydrogen cyanide.

2-hydroxypropanenitrile [1]

- (iii) Name the mechanism for the reaction of ethanal with hydrogen cyanide.

nucleophilic addition [1]

- (iv) Draw the three-dimensional structures for the two optical isomers of the hydroxynitrile formed in (b)(i).



[2]

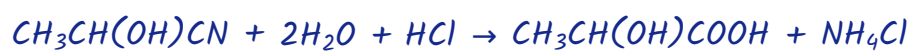


(v) Define the term **optical isomers**.

*Molecules with the same structural formula which are
non-superimposable mirror images of each other.*

[1]

(vi) Write the equation for the acid hydrolysis of the hydroxynitrile formed in
(b)(i) to produce lactic acid.



[2]

(vii) State why the lactic acid produced is not optically active.

*It is a racemic mixture: equal amounts of both optical isomers
form, so their effects on plane-polarised light cancel.*

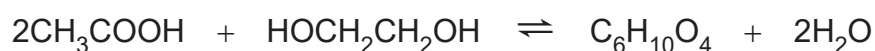
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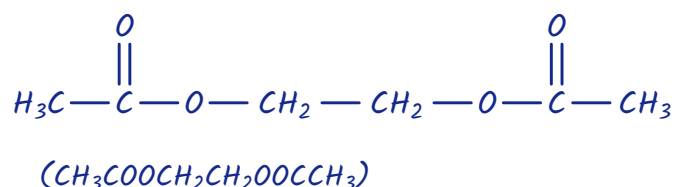
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13 Ethanoic acid and ethane-1,2-diol react together to form the diester $C_6H_{10}O_4$.



(a) Draw the structure for the diester $C_6H_{10}O_4$.



[1]

(b) A mixture of 0.550 moles of ethanoic acid and 0.205 moles of ethane-1,2-diol was allowed to reach equilibrium.

Substance	CH_3COOH	$HOCH_2CH_2OH$	$C_6H_{10}O_4$	H_2O
Initial amount in mixture /mol	0.550	0.205	0	0
Equilibrium amount in mixture /mol	0.260	0.060	0.145	0.290

(i) Complete the table above.

[3]



(ii) Write an expression for the equilibrium constant, K_c , for this reaction.

$$K_c = \frac{[C_6H_{10}O_4][H_2O]^2}{[CH_3COOH]^2[HOCH_2CH_2OH]}$$

[1]

(iii) Explain why the total volume of the mixture is not needed to calculate the value of K_c .

There are the same number of moles on both sides of the equation (3), so the volumes cancel out in the K_c expression and K_c has no units.

[1]

(iv) Calculate the value of K_c for this equilibrium reaction.

$$K_c = \frac{(0.145)(0.290)^2}{(0.260)^2(0.060)} = 3.01 \text{ (no units)}$$

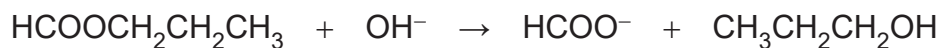
Answer 3.01 [2]

[Turn over]

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- 14 (a) Propyl methanoate is a liquid ester. It can be hydrolysed in alkaline conditions as shown by the equation below.



Describe how you would follow the rate of this reaction with respect to hydroxide ions using pH and how you would use your results to find the order of reaction with respect to hydroxide ions.

In this question you will be assessed on your written communication skills including the use of specialist scientific terms.

Mix known volumes of the ester and the sodium hydroxide solution

at a constant temperature and start a stopwatch.

Record the pH of the mixture at regular time intervals using a calibrated pH meter.

For each reading calculate $[\text{H}^+] = 10^{-\text{pH}}$, then calculate the concentration of OH^- ions using K_w : $[\text{OH}^-] = K_w \div [\text{H}^+]$.

Plot a graph of concentration of OH^- against time.

Draw tangents to the curve at different concentrations; the gradient of each tangent equals the rate at that concentration.

Plot a graph of rate against concentration of hydroxide ions. The shape of this graph shows the order: a horizontal line is zero order, a straight line through the origin is first order and an upward curve is second order.

[6]



(b) Some data for the hydrolysis of propyl methanoate are given below.

Experiment	$[\text{HCOOCH}_2\text{CH}_2\text{CH}_3]$ /mol dm ⁻³	$[\text{OH}^-]$ /mol dm ⁻³	Initial rate of the reaction ($\times 10^{-4}$) /mol dm ⁻³ s ⁻¹
1	0.040	0.030	4.00
2	0.040	0.045	6.00
3	0.060	0.045	9.00
4	0.120	0.060	to be calculated

(i) State the order of the reaction with respect to propyl methanoate.

Answer 1 [1]

(ii) State the order of the reaction with respect to hydroxide ions.

Answer 1 [1]

(iii) Calculate the initial rate of reaction for **Experiment 4**.

$$\text{rate} = k[\text{ester}][\text{OH}^-]; k = 4.00 \times 10^{-4} \div (0.040 \times 0.030) = 0.333$$

$$\text{rate} = 0.333 \times 0.120 \times 0.060 = 24 \times 10^{-4} = 2.4 \times 10^{-3}$$

Answer 2.4×10^{-3} mol dm⁻³ s⁻¹ [1]

(iv) State the effect, if any, of increasing the temperature on the value of the rate constant.

The rate constant increases. [1]

[Turn over]



(c) Fats are formed from glycerol and fatty acids. The table below shows some fatty acids.

Fatty acid	IUPAC name	Formula
A	octadecanoic acid	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$
B	octadec-9-enoic acid	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
C	octadeca-9,12-dienoic acid	$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$

(i) State the IUPAC name of glycerol.

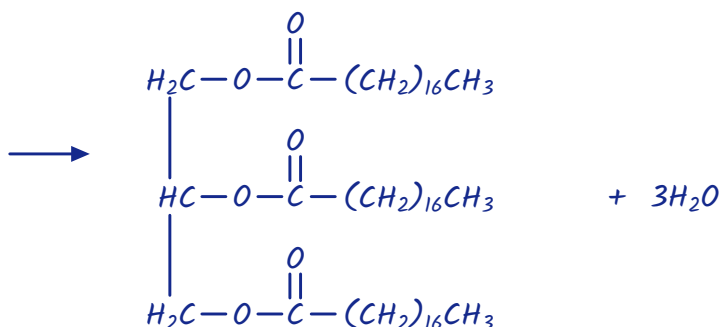
propane-1,2,3-triol

[1]

(ii) Write the formula for the fatty acid **B** in the table.

[1]

(iii) Write the equation for the formation of a fat from one molecule of glycerol and three molecules of fatty acid **A**.



[2]





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[Turn over



- 15 Group I elements are highly reactive and form a variety of compounds many of which are very soluble in water.

(a) Rubidium ignites spontaneously when exposed to air to form rubidium oxide.

The following enthalpy changes can be used to calculate the standard enthalpy of formation of rubidium oxide.

Enthalpy change	Equation	$\Delta H / \text{kJ mol}^{-1}$
A	$\text{Rb(s)} \rightarrow \text{Rb(g)}$	+86
B	$\text{Rb(g)} \rightarrow \text{Rb}^+(\text{g}) + \text{e}^-$	+402
C	$\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{O}(\text{g})$	+249
D	$\text{Rb}_2\text{O(s)} \rightarrow 2\text{Rb}^+(\text{g}) + \text{O}^{2-}(\text{g})$	+2161
E	$\text{O}(\text{g}) + \text{e}^- \rightarrow \text{O}^-(\text{g})$	-142
F	$\text{O}^-(\text{g}) + \text{e}^- \rightarrow \text{O}^{2-}(\text{g})$	+844

(i) Write an equation for the standard enthalpy of formation of rubidium oxide.



(ii) Name the enthalpy changes C, D and E in the table above.

C enthalpy of atomisation of oxygen

D lattice enthalpy of rubidium oxide

E first electron affinity of oxygen [3]



(iii) Calculate the standard enthalpy of formation of rubidium oxide.

$$\begin{aligned}\Delta H_f &= 2A + 2B + C + E + F - D \\ &= 2(+86) + 2(+402) + (+249) + (-142) + (+844) - (+2161) \\ &= -234 \text{ kJ mol}^{-1}\end{aligned}$$

Answer -234 kJ mol⁻¹ [2]

(b) Rubidium reacts vigorously with gaseous iodine to form the white solid, rubidium iodide.

(i) Write an equation, including state symbols, for the formation of rubidium iodide.



(ii) Using the following data, calculate the enthalpy of solution of rubidium iodide.



$$\begin{aligned}\Delta H_{\text{sol}} &= -(\text{lattice formation enthalpy}) + \Delta H_{\text{hyd}}(\text{Rb}^+) + \Delta H_{\text{hyd}}(\text{I}^-) \\ &= (+617) + (-296) + (-308) \\ &= +13 \text{ kJ mol}^{-1}\end{aligned}$$

Answer +13 kJ mol⁻¹ [2]

[Turn over]

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- (c) Sodium nitrate decomposes on heating, to form sodium nitrite and oxygen, as shown by the equation below.



The minimum temperature required for this decomposition is 968 K.

The table below shows some standard enthalpy of formation data and some entropy values.

Substance	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	Entropy / $\text{J K}^{-1} \text{mol}^{-1}$
$\text{NaNO}_3(\text{s})$	-467	to be calculated
$\text{NaNO}_2(\text{s})$	-359	120
$\text{O}_2(\text{g})$	0	205

- (i) What is the systematic name for sodium nitrite?

sodium nitrate(III)

[1]

- (ii) Suggest why the decomposition temperature of potassium nitrate would be higher than the decomposition temperature of sodium nitrate.

The potassium cation is larger than the sodium cation, so it has a less polarising effect on the nitrate ion (distorts it less).

[2]

- (iii) Calculate the enthalpy change for the decomposition of sodium nitrate as shown by the equation below:



$$\Delta H = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$$

$$= 2(-359) + 0 - 2(-467)$$

$$= -718 + 934 = +216 \text{ kJ}$$

Answer +216 kJ [2]



- (iv) Using the minimum temperature required for the decomposition (968 K) and your answer to (c)(iii), calculate the entropy change in $\text{J K}^{-1} \text{mol}^{-1}$ for the decomposition.

at the minimum temperature $\Delta G = 0$, so $\Delta H = T\Delta S$

$$\Delta S = \Delta H \div T = 216 \div 968$$

$$= 0.223 \text{ kJ K}^{-1} \text{mol}^{-1}$$

$$= +223 \text{ J K}^{-1} \text{mol}^{-1}$$

Answer +223 $\text{J K}^{-1} \text{mol}^{-1}$ [3]

- (v) Using your answer to (c)(iv), calculate the entropy value for sodium nitrate.

$$\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$$

$$223 = 2(120) + 205 - 2S(\text{NaNO}_3)$$

$$2S(\text{NaNO}_3) = 445 - 223 = 222$$

$$S(\text{NaNO}_3) = 111 \text{ J K}^{-1} \text{mol}^{-1}$$

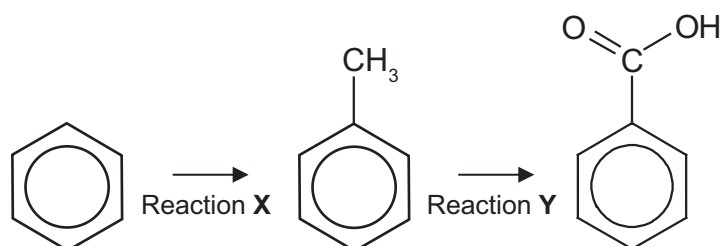
Answer 111 $\text{J K}^{-1} \text{mol}^{-1}$ [2]

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- 16 (a) Benzoic acid is formed from benzene in a process which involves two reactions X and Y.



During Reaction X, benzene reacts with chloromethane in the presence of aluminium chloride. In Reaction Y, methylbenzene is heated with acidified potassium dichromate(VI) solution.

- (i) State the function of aluminium chloride during Reaction X.

It is a catalyst (halogen carrier).

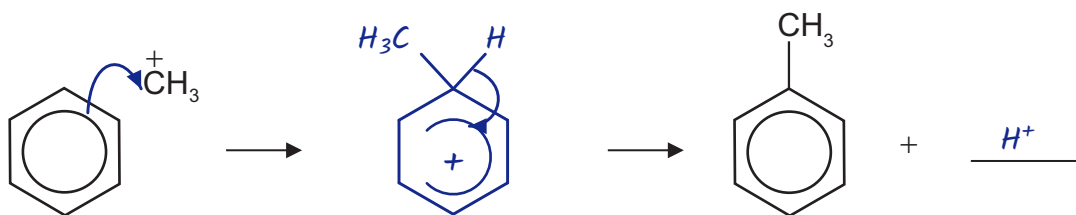
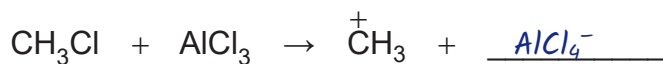
[1]

- (ii) Name the mechanism for Reaction X.

electrophilic substitution

[1]

- (iii) The mechanism for Reaction X is shown below. Complete the mechanism.



[5]



(iv) Suggest the type of reaction that is taking place during Reaction Y.

oxidation [1]

(v) Benzoic acid reacts with phosphorus pentachloride. Write an equation for this reaction.

$C_6H_5COOH + PCl_5 \rightarrow C_6H_5COCl + HCl + POCl_3$ [1]

(b) Methyl benzoate, a colourless liquid ester, is formed by the reaction of benzoic acid with methanol in the presence of a catalyst. The crude methyl benzoate distillate is collected over the temperature range 197 °C to 201 °C.

(i) Name a suitable catalyst for this reaction.

concentrated sulfuric acid [1]

(ii) The crude ester is purified and a pure sample of methyl benzoate is collected at 199 °C.

Outline, in general, the three main steps carried out in the purification of the crude ester to obtain a pure sample of methyl benzoate at 199 °C.

Step 1. Shake the crude ester with sodium carbonate solution in a separating funnel and discard the aqueous layer.

Step 2. Dry the ester with anhydrous sodium sulfate and filter (decant) it off.

Step 3. Distil, collecting the fraction that boils at 199 °C.

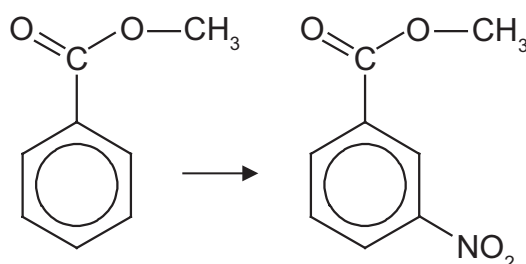
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- (c) Nitration of methyl benzoate produces methyl 3-nitrobenzoate. A nitrating mixture is used in this reaction.



- (i) Name the two reagents which are mixed together to form the nitrating mixture.

concentrated nitric acid

concentrated sulfuric acid

[2]

- (ii) The nitronium ion forms in the nitrating mixture. Write an equation for the formation of the nitronium ion.



[2]



- (iii) Describe, including experimental details, how you would prepare a pure, dry sample of methyl 3-nitrobenzoate from methyl benzoate and the nitrating mixture.

In this question you will be assessed on your written communication skills including the use of specialist scientific terms.

Dissolve some methyl benzoate in concentrated sulfuric acid in a conical flask and cool the solution in ice.

Add the nitrating mixture drop by drop, stirring with a thermometer and keeping the temperature below 10 °C.

Allow the mixture to stand at room temperature for 15 minutes.

Pour the mixture onto crushed ice and stir until all the ice has melted and crystals of methyl 3-nitrobenzoate form.

Filter off the crystals using Büchner (suction) filtration.

Recrystallise from the minimum volume of hot ethanol, then filter again.

Dry the crystals in a desiccator.

[6]

THIS IS THE END OF THE QUESTION PAPER



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General Information

1 tonne = 10^6 g

1 metre = 10^9 nm

One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm³

Avogadro Constant = 6.02×10^{23} mol⁻¹

Planck Constant = 6.63×10^{-34} Js

Specific Heat Capacity of water = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light = $3 \times 10^8 \text{ m s}^{-1}$



Characteristic absorptions in IR spectroscopy

Wavenumber/cm ⁻¹	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C ₆ H ₅ –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C ₆ H ₅	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations chemistry

THE PERIODIC TABLE OF ELEMENTS																		III	IV	V	VI	VII	0	
Group																								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18							
1 H Hydrogen																	4 He Helium							
7 Li Lithium	9 Be Beryllium											11 B Boron	12 C Carbon	14 N Nitrogen	16 O Oxygen	19 F Fluorine	20 Ne Neon							
23 Na Sodium	24 Mg Magnesium											27 Al Aluminium	28 Si Silicon	31 P Phosphorus	32 S Sulfur	35.5 Cl Chlorine	40 Ar Argon							
39 K Potassium	40 Ca Calcium	45 Sc Scandium	48 Ti Titanium	51 V Vanadium	52 Cr Chromium	55 Mn Manganese	56 Fe Iron	59 Co Cobalt	59 Ni Nickel	64 Cu Copper	65 Zn Zinc	70 Ga Gallium	73 Ge Germanium	75 As Arsenic	79 Se Selenium	80 Br Bromine	84 Kr Krypton							
85 Rb Rubidium	88 Sr Strontium	89 Y Yttrium	91 Zr Zirconium	93 Nb Niobium	96 Mo Molybdenum	98 Tc Technetium	101 Ru Ruthenium	103 Rh Rhodium	106 Pd Palladium	108 Ag Silver	112 Cd Cadmium	115 In Indium	119 Sn Tin	122 Sb Antimony	128 Te Tellurium	127 I Iodine	131 Xe Xenon							
133 Cs Caesium	137 Ba Barium	139 La [*] Lanthanum	178 Hf Hafnium	181 Ta Tantalum	184 W Tungsten	186 Re Rhenium	190 Os Osmium	192 Ir Iridium	195 Pt Platinum	197 Au Gold	201 Hg Mercury	204 Tl Thallium	207 Pb Lead	209 Bi Bismuth	210 Po Polonium	210 At Astatine	222 Rn Radon							
223 Fr Francium	226 Ra Radium	227 Ac [†] Actinium	261 Rf Rutherfordium	262 Db Dubnium	266 Sg Seaborgium	264 Bh Bohrium	277 Hs Hassium	268 Mt Meitnerium	271 Ds Darmstadtium	272 Rg Roentgenium	285 Cn Copernicium													
			140 Ce Cerium	141 Pr Praseodymium	144 Nd Neodymium	145 Pm Promethium	150 Sm Samarium	152 Eu Europium	157 Gd Gadolinium	159 Tb Terbium	162 Dy Dysprosium	165 Ho Holmium	167 Er Erbium	169 Tm Thulium	173 Yb Ytterbium	175 Lu Lutetium								
			232 Th Thorium	231 Pa Protactinium	238 U Uranium	237 Np Neptunium	242 Pu Plutonium	243 Am Americium	247 Cm Curium	245 Bk Berkelium	251 Cf Californium	254 Es Einsteinium	253 Fm Fermium	256 Md Mendelevium	254 No Nobelium	257 Lr Lawrencium								
			90	91	92	93	94	95	96	97	98	99	100	101	102	103								
			* 58 – 71 Lanthanum series † 90 – 103 Actinium series																					
			a X b a = relative atomic mass (approx) x = atomic symbol b = atomic number																					