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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Formulae, Equations and Amounts of Substance (5)

A Level Chemistry Topic 5

37 questions · 437 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

37 questions · 437 marks · grouped by sub-topic



SUB-TOPIC 5(a)

FORMULAE AND EQUATIONS

8 questions in this sub-topic · 97 marks · lowest tariff first



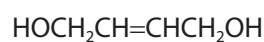
2 Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.



A

or



B

- (a) Deduce a **chemical** test which would give a positive result for **A** but **not** for **B**.
Include the reagent and observation.

(2)

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- (b) Deduce a **chemical** test which would give a positive result for **B** but **not** for **A**.
Include the reagent and observation.

(2)

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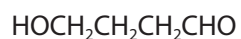
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- (c) Another student suggests that the compound could contain an aldehyde and an alcohol functional group, with structure **C**.



C

Complete the table to show how the infrared spectra of **A**, **B** and **C** would be expected to differ in the wavenumber range **1800–1600 cm⁻¹**.
Use information from the Data Booklet.

(3)

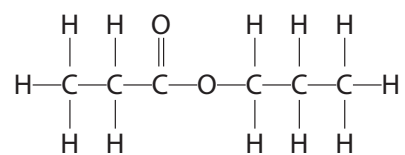
Absorbance	Wavenumber range / cm ⁻¹
Absorbance expected in infrared spectrum of A but not in B or C	
Absorbance expected in infrared spectrum of B but not in A or C	
Absorbance expected in infrared spectrum of C but not in A or B	

(Total for Question 2 = 7 marks)



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

(a) Propyl propanoate has the structure shown.



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

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

(5)



- (b) Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed. It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of but-1-ene and but-2-ene.

Deduce the structures of **B** and **A**. Justify your structure of **B**.

(3)

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(Total for Question 3 = 8 marks)



2 This question is about alkenes.

(a) Which of these has the molecular formula C_6H_{10} ?

(1)

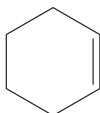
☐ A



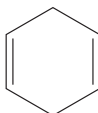
☐ B



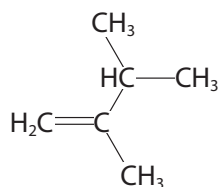
☐ C



☐ D



(b) What is the systematic name of this alkene?



(1)

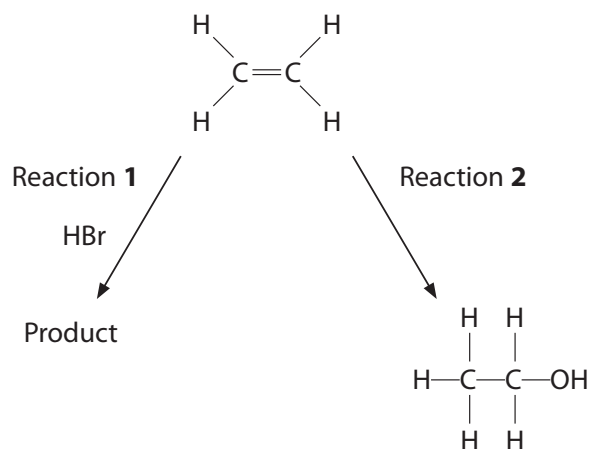
☐ A 2-methylpent-1-ene

☐ B 3-methylpent-1-ene

☐ C 2,3-dimethylbut-1-ene

☐ D 2,3-dimethylbut-3-ene

(c) Two reactions of ethene are shown.



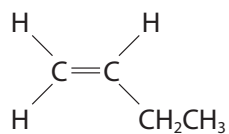
Complete the table.

(3)

Reaction	Reagent and condition	Product
1	HBr at room temperature	
2		$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$



(d) But-1-ene has the structure



- (i) Draw the structure of the polymer formed when but-1-ene polymerises.
Include **two** repeat units.

(1)

- (ii) Calculate the number of molecules in 70.0 g of but-1-ene.
[Avogadro constant = $6.02 \times 10^{23} \text{ mol}^{-1}$]

(2)

(Total for Question 2 = 8 marks)



- 2 This question is about lactic acid (2-hydroxypropanoic acid), $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. Lactic acid is used to make biodegradable polymers.

(a) Lactic acid can be made in a two-step synthesis starting from ethanal, CH_3CHO .

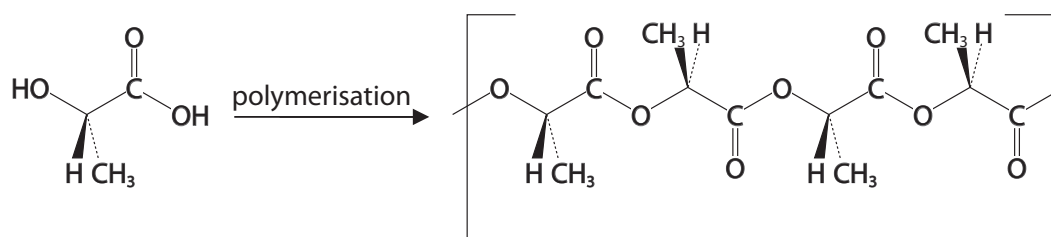
Devise a reaction scheme for a two-step synthesis.

Include in your answer all reagents and conditions, the type of reaction occurring at each step, and a balanced equation for each reaction.

State symbols are **not** required.

(7)

(b) Polymerisation of lactic acid forms poly(lactic acid) as shown in the diagram.



(i) State the type of polymerisation occurring in this reaction.

(1)

(ii) **On the diagram**, draw a circle around the repeat unit of the polymer.

(1)

(Total for Question 2 = 9 marks)

5 This question is about hydrocarbons.

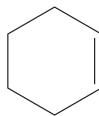
(a) Which of these molecular formulae represents a non-cyclic, saturated hydrocarbon? (1)

- ☐ A C_6H_6
- ☐ B C_6H_{10}
- ☐ C C_6H_{12}
- ☐ D C_6H_{14}

(b) How many **structural** isomers are there with the molecular formula C_5H_{12} ? (1)

- ☐ A 2
- ☐ B 3
- ☐ C 4
- ☐ D 5

(c) How many σ bonds and π bonds are there in one molecule of cyclohexene?

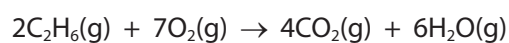


(1)

	σ bonds	π bonds
☐ A	5	2
☐ B	6	1
☐ C	15	2
☐ D	16	1

(d) When hydrocarbons undergo complete combustion, there is a change in the total volume of gases.

(i) Ethane burns in excess oxygen.



All gas volumes are measured at the same temperature and pressure when water is a gas.

What is the **increase** in the total volume when 100 cm^3 of ethane is burned in excess oxygen?

(1)

☐ A 50 cm^3

☐ B 100 cm^3

☐ C 200 cm^3

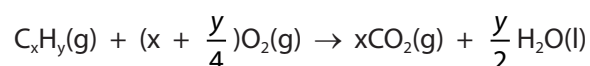
☐ D 500 cm^3



- (ii) A combustion experiment was carried out using conditions under which water was a liquid.

A cyclic hydrocarbon, C_xH_y , was mixed with excess oxygen and ignited. Under the conditions of the experiment, this hydrocarbon was gaseous and had a volume of 25 cm^3 .

The equation for the complete combustion of C_xH_y is



The total gas volume **decreased** by 75 cm^3 .

The remaining gases were shaken with aqueous sodium hydroxide and the total gas volume **decreased** by a further 125 cm^3 .

All gas volumes were measured at the same temperature and pressure.

Suggest the identity of the cyclic hydrocarbon by calculating the molecular formula of C_xH_y .

Include the **skeletal formula** of the cyclic hydrocarbon.

(3)



(e) Propene reacts with iodine monochloride, ICl, by an electrophilic addition mechanism.

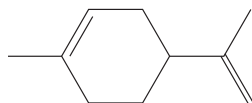
Draw the mechanism for the reaction between propene and iodine monochloride to form the **major** product.

Include the dipole on the ICl molecule, curly arrows and any relevant lone pairs of electrons.

(4)



(f) Limonene is obtained from the oil in lemon peel and it is the only alkene present.



0.500 g of the oil reacted with exactly 30.6 cm^3 of a solution of bromine dissolved in cyclohexane with a concentration of $0.200 \text{ mol dm}^{-3}$.

Calculate the percentage by mass of limonene in the oil.

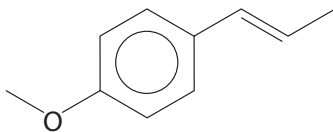
Give your answer to an appropriate number of significant figures.

Assume that there is nothing else in the oil that reacts with bromine.

(4)

(Total for Question 5 = 15 marks)

- 8 The flavour of aniseed and liquorice is mainly due to anethole, which has the structure shown.



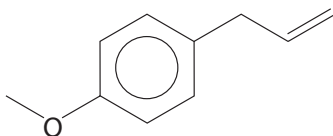
- (a) Give the molecular formula of anethole.

(1)

- (b) Draw the stereoisomer of anethole.

(1)

- (c) A structural isomer of anethole is estragole, which has the structure shown.



Give a reason why anethole shows stereoisomerism but estragole does **not**.

(1)

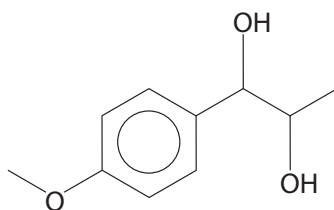
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(d) What is the reagent required to convert anethole to the diol shown?



(1)

- ☐ **A** acidified potassium manganate(VII)
- ☐ **B** aqueous sodium hydroxide
- ☐ **C** ethanolic potassium hydroxide
- ☐ **D** steam with an acid catalyst

(e) The structure of anethole can be drawn with a delocalised model of the benzene ring or with the Kekulé benzene ring structure as shown.

delocalised model	Kekulé structure

- (i) Describe how the orbitals of carbon atoms overlap to form the σ -bonds and the π -bonds in the delocalised model of the benzene ring. You may include a labelled diagram in your answer.

(3)

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- (ii) Explain why the delocalised model of the benzene ring is the preferred representation rather than the Kekulé cyclic triene.
Refer to **one** physical and **one** thermodynamic measurement in your answer.

(4)

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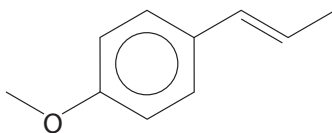


- (f) Anethole is also present in some alcoholic drinks such as the Greek liquor, ouzo.

The anethole is responsible for the so-called 'ouzo effect'. This effect is the transparent ouzo liquor turning milky when water is added.

The addition of water causes the anethole to form oily droplets which result in a stable milky emulsion.

Deduce the solubility of anethole in ethanol and in water from the 'ouzo effect'. Justify your answer with reference to the anethole structure shown, but detailed descriptions of intermolecular forces are not required.



anethole

(3)

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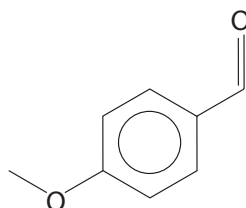
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- (g) A derivative of anethole is anisaldehyde, which has the structure shown.



What is the number of peaks in the ^{13}C NMR spectrum of anisaldehyde?

(1)

- ☐ A 5
- ☐ B 6
- ☐ C 7
- ☐ D 8

(Total for Question 8 = 15 marks)

7 This question is about amines.

(a) Aliphatic amines may be prepared from halogenoalkanes or from nitriles.

Assess these two methods for the preparation of butylamine.
Consider the reagents, the conditions needed, atom economy and
the type of reaction.
Include equations.

(7)

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(b) Preparation of the aromatic amine, benzene-1,3-diamine, requires different conditions.

- (i) Write an equation for the preparation of benzene-1,3-diamine from the corresponding dinitro-compound and include necessary conditions.

(3)

Conditions



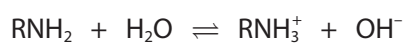
- (ii) Explain the factors affecting the basicity of benzene-1,3-diamine and propane-1,3-diamine.

Include reference to information given in the table.

Substance	pK_{b1}
benzene-1,3-diamine	8.89
propane-1,3-diamine	3.83

K_{b1} is the equilibrium constant for the first protonation reaction.

The equation is shown.



(4)

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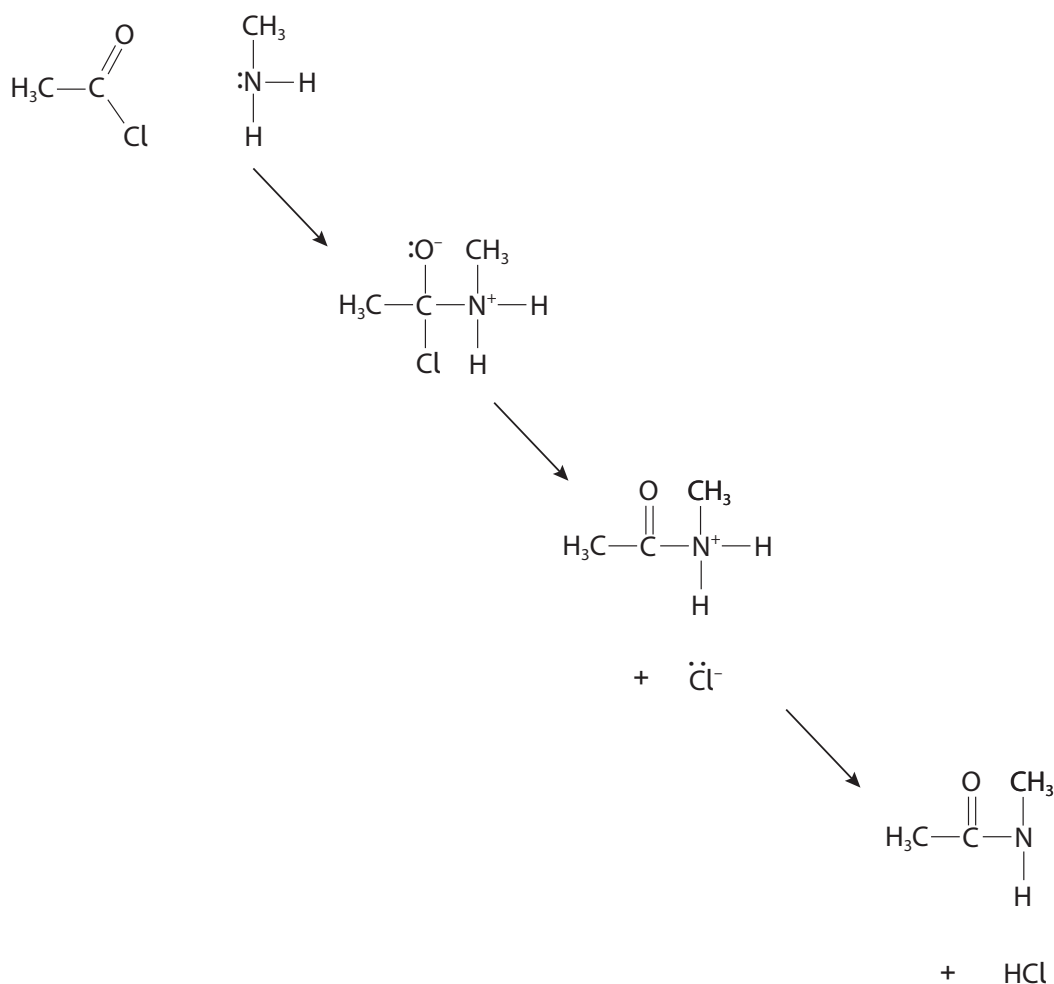
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- (c) Methylamine reacts with ethanoyl chloride to produce an amide.
An incomplete outline of the mechanism is shown.

Add curly arrows to show the movement of the electrons in the mechanism.

(3)



(Total for Question 7 = 17 marks)

8 This question is about some carbonyl compounds with the molecular formula $C_5H_{10}O$.

- (a) Describe a chemical test, and its result, to distinguish between pentan-2-one, $CH_3CH_2CH_2COCH_3$, and pentan-3-one, $CH_3CH_2COCH_2CH_3$.

(2)

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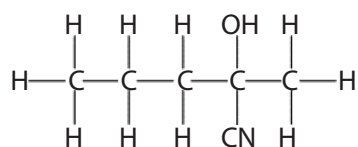
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- (b) Pentan-2-one reacts with hydrogen cyanide in the presence of cyanide ions to form 2-hydroxy-2-methylpentanenitrile.



2-hydroxy-2-methylpentanenitrile

- (i) Draw the mechanism for the reaction between pentan-2-one and hydrogen cyanide in the presence of cyanide ions.

Include curly arrows and any relevant lone pairs.

(4)



- (ii) The product of this reaction, 2-hydroxy-2-methylpentanenitrile, has a chiral centre.
Explain why a racemic mixture of 2-hydroxy-2-methylpentanenitrile is formed in this reaction.

(2)

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- (c) An aldehyde with molecular formula $C_5H_{10}O$ has a ^{13}C NMR spectrum with three peaks.

The high resolution ^1H NMR spectrum of this aldehyde has two peaks and neither of them is split.

Deduce the **displayed** formula of this aldehyde.
Justify your answer by referring to both NMR spectra.

(4)

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Include the reagents and the structures of the organic products formed in any reactions that take place.



(Total for Question 8 = 18 marks)

SUB-TOPIC 5(b)

MOLES, MASSES AND GAS VOLUMES

9 questions in this sub-topic · 75 marks · lowest tariff first



1 What is the total number of **ions** in 26.4 g of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$?

[Molar mass of $(\text{NH}_4)_2\text{SO}_4 = 132 \text{ g mol}^{-1}$ Avogadro constant = $6.0 \times 10^{23} \text{ mol}^{-1}$]

☐ A 4.0×10^{22}

☐ B 1.2×10^{23}

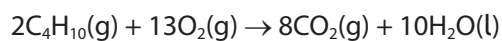
☐ C 2.4×10^{23}

☐ D 3.6×10^{23}

(Total for Question 1 = 1 mark)



2 The equation for the complete combustion of butane is



What is the minimum volume of oxygen, at room temperature and pressure (r.t.p.), needed for the complete combustion of 0.200 mol of butane?

[Molar volume of a gas at r.t.p. = $24.0 \text{ dm}^3 \text{ mol}^{-1}$]

- ☐ A 4.8 dm^3
- ☐ B 9.6 dm^3
- ☐ C 31.2 dm^3
- ☐ D 62.4 dm^3

(Total for Question 2 = 1 mark)



4 Traditionally, high-flying aircraft and Formula 1 racing cars have had their tyres inflated with nitrogen gas instead of air. Recently, this practice has been extended to some other cars.

(a) A car tyre is filled with nitrogen gas to a volume of 8.98 dm^3 and a pressure of 207 kPa at 20°C .

(i) Using the Ideal Gas Equation, calculate the mass of nitrogen gas, in grams, present in the car tyre under these conditions. Give your answer to an appropriate number of significant figures.

(3)

(ii) During a car journey, the tyres become warm. Use the Ideal Gas Equation to deduce the effect that this has on the pressure in the tyres.

(1)

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(b) One reason for the use of nitrogen gas in car tyres is that less gas is lost from the tyres during use because nitrogen molecules are larger than oxygen molecules. A suggested explanation for this is that nitrogen atoms are larger than oxygen atoms.

Explain why a nitrogen atom is larger than an oxygen atom.

(2)

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(Total for Question 4 = 6 marks)



3 This question is about the molar masses of three organic compounds, **X**, **Y** and **Z**.

- (a) The accurate relative atomic masses, A_r , of four of the elements that could be present in an organic compound are shown.

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

The mass spectrum of organic compound **X** gives a molecular ion peak at $m/z = 60.0323$

What is compound **X**?

(1)

- ☐ **A** ethanamide, CH_3CONH_2
- ☐ **B** ethanoic acid, CH_3COOH
- ☐ **C** trimethylamine, $(\text{CH}_3)_3\text{N}$
- ☐ **D** urea, $\text{CO}(\text{NH}_2)_2$

- (b) 9.90 g of a gaseous organic compound, **Y**, occupies a volume of 5.40 dm^3 at room temperature and pressure (r.t.p.).

Calculate the molar mass of the compound **Y**.

[molar gas volume at r.t.p. = $24.0 \text{ dm}^3 \text{ mol}^{-1}$]

(2)



- (c) A quantity of a volatile organic liquid, **Z**, is placed in a 60.0 cm^3 flask and heated to 95.0°C . When all the liquid has vaporised, the flask is sealed.

Mass of vapour = 0.170 g

Pressure = 100.6 kPa

Gas constant (R) = $8.31\text{ J mol}^{-1}\text{ K}^{-1}$

Calculate the molar mass of compound **Z**, giving your answer to an appropriate number of significant figures.

Assume there was no air left in the flask once the liquid **Z** had vaporised.

(4)

(Total for Question 3 = 7 marks)



4 This question is about some hydrocarbons.

- (a) A 2.50 g sample of a hydrocarbon gave 7.59 g of carbon dioxide on complete oxidation.

Calculate the empirical formula of the hydrocarbon.

(4)



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

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

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

(4)



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

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

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

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

(5)

(c) Which of these is used to convert a dicarboxylic acid into a diol?

(1)

- ☐ **A** LiAlH_4 and ether
- ☐ **B** KMnO_4 and H_2SO_4
- ☐ **C** Sn and HCl
- ☐ **D** $\text{Na}_2\text{Cr}_2\text{O}_7$ and H_2SO_4

(Total for Question 8 = 10 marks)



5 This question is about cobalt complexes.

- (a) A sample of cobalt(II) chloride was dissolved in aqueous ammonia, $\text{NH}_3(\text{aq})$. During the process, a stream of oxygen was gently bubbled through the solution to oxidise the cobalt(II) ion.

A coloured solid, **R**, was extracted from the solution. A pure sample of this solid was found to contain the masses of the elements shown and had a molar mass of 233.4 g mol^{-1} .

Element	Mass / g
Co	1.26
N	1.20
H	0.257
Cl	2.28

- (i) Show that the empirical formula **and** the molecular formula of **R** is $\text{CoN}_4\text{H}_{12}\text{Cl}_3$. You must show your working.

(2)



- (ii) 1.00 g of **R** was dissolved in water forming a coloured solution of the complex ion, **Q**.

The solution was reacted with excess silver nitrate solution, forming 0.614 g of silver chloride, AgCl(s).

Calculate the number of moles of chloride ions released when 1 mol of **R** dissolves.

(2)

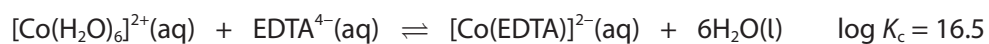
- (iii) Draw the three-dimensional shape of the complex ion, **Q**, using your answer to (a)(ii) to help deduce the formula and overall charge.

(3)



(b) An aqueous solution of cobalt(II) chloride contains the complex ion $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.

The dynamic equilibria shown occur when $\text{NH}_3(\text{aq})$ and $\text{EDTA}^{4-}(\text{aq})$ are each added to separate solutions of this complex ion.



(i) State what is meant by the term 'dynamic equilibrium'.

(2)

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(ii) Explain, in terms of equilibria and entropy, which of the three complex ions is the most stable.

(3)

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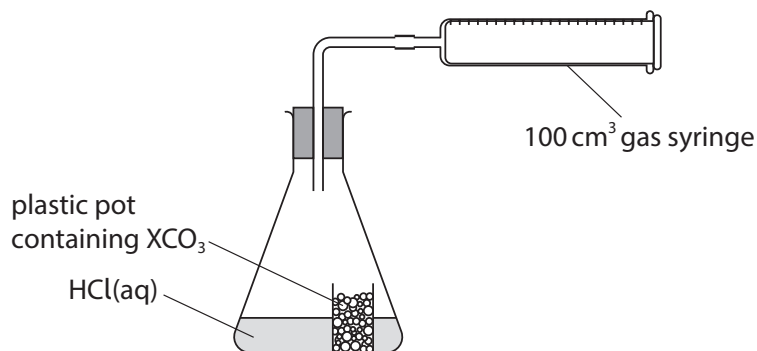
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(Total for Question 5 = 12 marks)

- 5 The kinetics of the reactions of hydrochloric acid with metal carbonates were investigated using the apparatus shown.



The equation for the reaction is shown.



- (a) One student used 0.355 g of calcium carbonate.

Calculate the minimum volume, in cm^3 , of 0.100 mol dm^{-3} hydrochloric acid that would completely react with this mass of calcium carbonate.
Give your answer to an appropriate number of significant figures.

[Calcium carbonate molar mass = 100.1 g mol^{-1}]

(4)

(b) State why powdered metal carbonate reacts faster than large lumps.

(1)

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(c) A second student used 4.19×10^{-3} mol of magnesium carbonate and suggested heating up the apparatus to speed up the rate of reaction.

- (i) If the use of heat means that the carbon dioxide gas is at a temperature of 74.0°C , then the apparatus shown would **not** give a measurable result.

Justify this comment by calculating the volume of carbon dioxide gas at this temperature using the ideal gas equation.

Assume that the pressure remains at 100 kPa throughout the experiment.

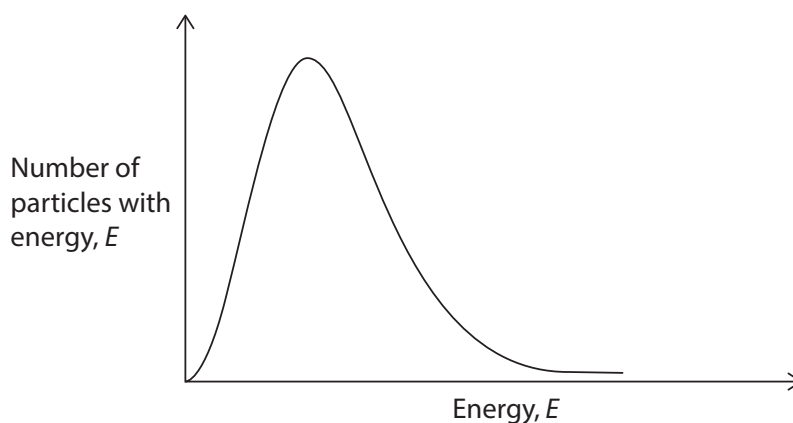
(4)



- (ii) The student suggested that the Maxwell–Boltzmann distribution of molecular energies for a reaction mixture at a particular temperature is shown in a graph.

Explain, by adding another line to the graph **and** by annotating the graph, how heating the reaction mixture results in a faster reaction rate.

(3)



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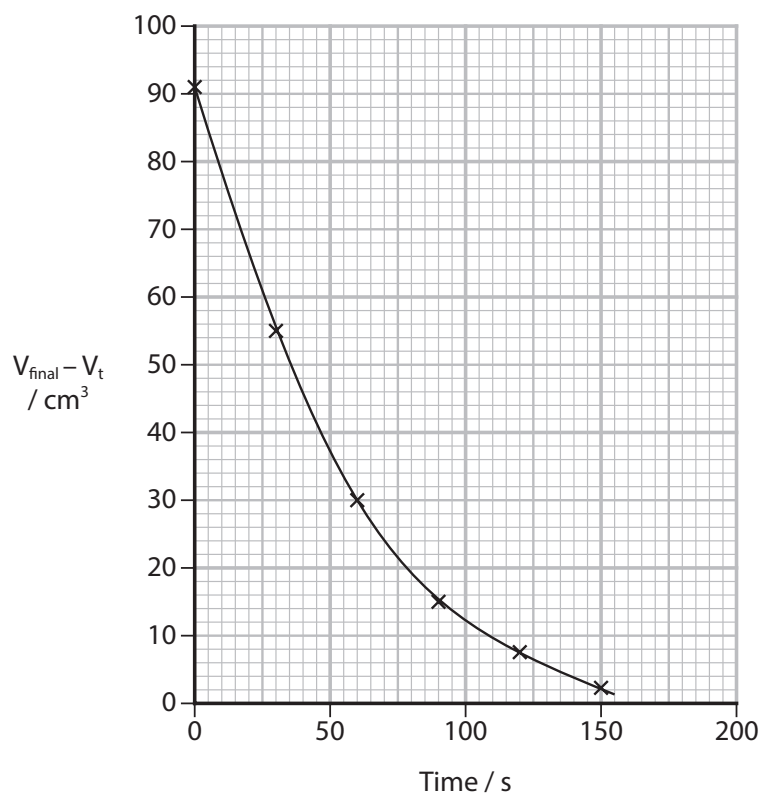
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- (d) A third student, in order to obtain the rate of reaction, measured the volume of gas produced at various times and used their data to plot the graph shown.



Determine the initial rate of this reaction.
You **must** show your working on the graph.
Include units in your answer.

(2)

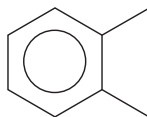
(Total for Question 5 = 14 marks)



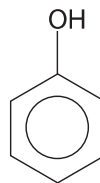
- 5 This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.



ethylbenzene



xylene



phenol

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

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

(1)

- (ii) Draw the mechanism for this reaction.

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

(5)

(iii) Explain whether phenol is likely to be less or more reactive than benzene with the chloroalkane from (a)(i).

(3)

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- (b) A student carried out an experiment to determine the molar mass of xylene.

The student's sample of xylene vapour had a mass of 0.271 g.

At a temperature of 165 °C and a pressure of 118 kPa, this sample had a volume of 70.5 cm³.

Use the Ideal Gas Equation to calculate the molar mass, in g mol⁻¹, of this sample.

Give your answer to an appropriate number of significant figures.

You **must** show your working.

(4)

- (c) The time taken for a compound to pass through the column in gas chromatography is called the retention time.

Explain why different compounds will have different retention times in the same column, under the same conditions.

(2)

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(Total for Question 5 = 15 marks)



SUB-TOPIC 5(c)

SOLUTIONS, TITRATIONS AND CONCENTRATIONS

17 questions in this sub-topic · 235 marks · lowest tariff first



2 This question is about acids and bases.

(a) What is the order of **decreasing** pH for 0.100 mol dm⁻³ solutions of these three acids?

(1)

- ☐ A CH₃COOH > CH₂ClCOOH > HCl
- ☐ B HCl > CH₃COOH > CH₂ClCOOH
- ☐ C CH₂ClCOOH > CH₃COOH > HCl
- ☐ D HCl > CH₂ClCOOH > CH₃COOH

(b) A solution of methanoic acid, HCOOH, has a concentration of 0.240 mol dm⁻³ and a pH of 2.20.

Calculate the value of pK_a for methanoic acid.

(3)

(c) Which of these mixtures would form a buffer solution with a pH **below** 7?

(1)

- ☐ A NaOH(aq) and excess HCl(aq)
- ☐ B NaOH(aq) and excess CH₃COOH(aq)
- ☐ C excess NaOH(aq) and HCl(aq)
- ☐ D excess NaOH(aq) and CH₃COOH(aq)



(d) Bromothymol blue, methyl orange and phenolphthalein are indicators used in titrations.

Which, if any, of these indicators could be used for a titration of ammonia, $\text{NH}_3(\text{aq})$, with ethanoic acid, $\text{CH}_3\text{COOH}(\text{aq})$?

(1)

- ☐ **A** bromothymol blue
- ☐ **B** methyl orange
- ☐ **C** phenolphthalein
- ☐ **D** none of these three indicators

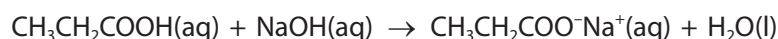
(Total for Question 2 = 6 marks)



3 The standard molar enthalpy change of neutralisation is the enthalpy change when an acid and an alkali react under standard conditions to form one mole of water.

- (a) An experiment was carried out to determine the enthalpy change of neutralisation for the reaction between propanoic acid and sodium hydroxide.

The equation for this reaction is



50.0 cm³ of sodium hydroxide solution, of concentration 1.00 mol dm⁻³, was placed in a polystyrene cup. The initial temperature was measured.

- (i) Which piece of equipment has the **smallest** measurement uncertainty for the measurement of 50.0 cm³ of sodium hydroxide solution?

(1)

	Equipment	Measurement uncertainty for each reading
☐ A	burette	±0.05 cm ³
☐ B	50 cm ³ measuring cylinder	±1 cm ³
☐ C	25 cm ³ pipette	±0.06 cm ³
☐ D	50 cm ³ pipette	±0.08 cm ³

- (ii) 50.0 cm³ of propanoic acid solution, of concentration 1.00 mol dm⁻³, was added and thoroughly mixed with the sodium hydroxide solution in the polystyrene cup.

The maximum temperature rise was 6.5 °C.

Calculate the enthalpy change of neutralisation for propanoic acid, in kJ mol⁻¹, giving your answer to the **nearest whole number**.

[Assume density of the mixture = 1.00 g cm⁻³, specific heat capacity of the mixture = 4.18 J g⁻¹ °C⁻¹]

(3)

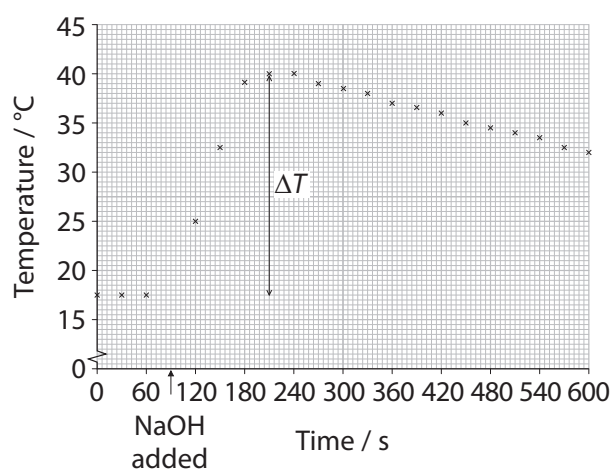


(b) Another experiment was carried out with a solution of ethanoic acid and sodium hydroxide solution of the same concentration.

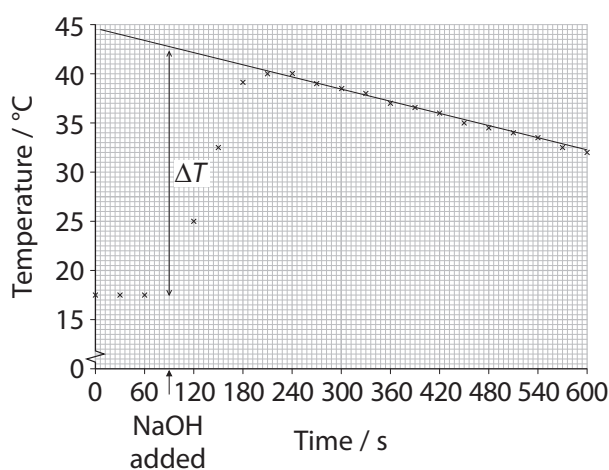
- (i) Which graph shows the correct way that the maximum temperature rise should be determined?

(1)

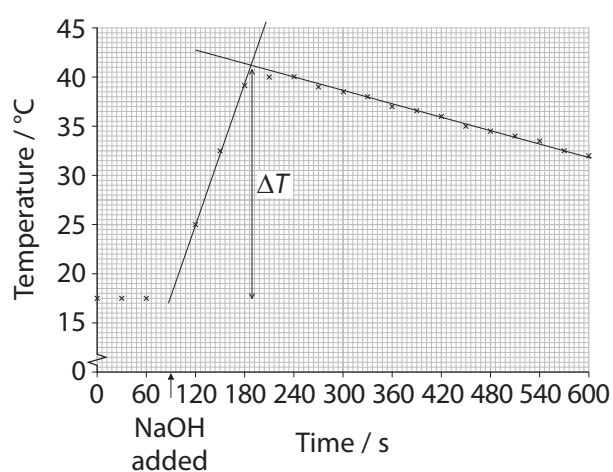
☐ A



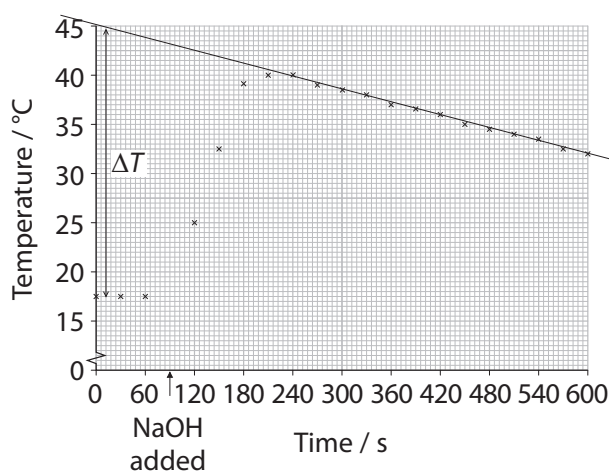
☐ B



☐ C



☐ D



- (ii) Explain why the data book value for the standard enthalpy change of neutralisation of ethanoic acid with sodium hydroxide is $-55.2 \text{ kJ mol}^{-1}$ but the value for hydrochloric acid is $-57.1 \text{ kJ mol}^{-1}$.

(2)

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(Total for Question 3 = 7 marks)



9 This question is about the analysis of some organic compounds.

- (a) A compound **A** ($\text{C}_3\text{H}_7\text{Cl}$) reacts with dilute aqueous sodium hydroxide to produce **B** ($\text{C}_3\text{H}_8\text{O}$). **B** can be oxidised to **C** ($\text{C}_3\text{H}_6\text{O}$), which cannot be oxidised any further.

A reacts with magnesium in dry ether to give **D** ($\text{C}_3\text{H}_7\text{MgCl}$). When carbon dioxide is passed through the solution of **D**, followed by acidification, **E** ($\text{C}_4\text{H}_8\text{O}_2$) is formed.

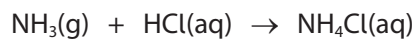
Identify the structures of **A** to **E**.

(5)



(b) An organic compound, **Q**, contains carbon, hydrogen and nitrogen only.

When a 1.19 g sample of the compound was heated with sodium hydroxide solution, all of the nitrogen was converted into ammonia. The ammonia was passed into 100.0 cm³ of 0.225 mol dm⁻³ hydrochloric acid.



25.0 cm³ portions of the resulting solution containing unreacted hydrochloric acid required a mean titre of 15.5 cm³ of 0.100 mol dm⁻³ sodium hydroxide for neutralisation.

Calculate the percentage of nitrogen in **Q**.

(5)

(Total for Question 9 = 10 marks)



- 9 Some hand sanitisers contain hydrogen peroxide (H_2O_2) as an active ingredient. The World Health Organization recommends that the concentration of H_2O_2 is between 3.0% and 6.0% by mass.

A higher concentration results in the hand sanitiser being caustic.

A lower concentration means the sanitiser would not be effective.

A sample of a colourless hand sanitiser of density 0.82 g cm^{-3} was analysed.

10.00 cm^3 of the sanitiser was dissolved in deionised water to give a total volume of 250.0 cm^3 . An acidified solution of potassium manganate(VII) with a concentration of $0.0200 \text{ mol dm}^{-3}$ was titrated against a 25.00 cm^3 sample of the diluted hand sanitiser solution.

- (a) The results of four titrations are shown in the table.

Complete the table by calculating the missing values.

(1)

Titration number	1	2	3	4
Final burette reading / cm^3	15.90	24.00	15.30	25.00
Initial burette reading / cm^3	0.00	8.45	0.05	
Titre / cm^3	15.90	15.55		15.65

- (b) The mean titre was calculated to be 15.60 cm^3 .

State how this value was determined.

(1)

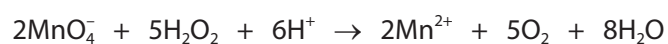
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(c) The ionic equation for the titration reaction is shown.



State the colour change that would be seen in the **flask** at the end-point of this titration.

(2)

From to

(d) Deduce by calculation whether the concentration of hydrogen peroxide in the hand sanitiser is within World Health Organization guidelines.

(5)



- (e) The uncertainty in the pipette volume is $\pm 0.04 \text{ cm}^3$. The uncertainty in each burette reading is $\pm 0.05 \text{ cm}^3$.

Calculate the percentage uncertainties for the pipette volume of 25.00 cm^3 and the burette volume of 15.55 cm^3 for titre 2.

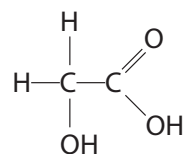
(2)

(Total for Question 9 = 11 marks)



- 8 2-Hydroxyethanoic acid, also known as glycolic acid, CH_2OHCOOH , is an alpha hydroxy acid used in some skincare products. It has a K_a value of $1.5 \times 10^{-4} \text{ mol dm}^{-3}$.

The structure of glycolic acid is



- (a) A solution of glycolic acid of concentration 0.1 mol dm^{-3} has a pH of 2.4

What is the approximate pH of the resulting solution after it has been diluted by a factor of 100?

(1)

- ☒ A 1.4
- ☒ B 2.4
- ☒ C 3.4
- ☒ D 4.4

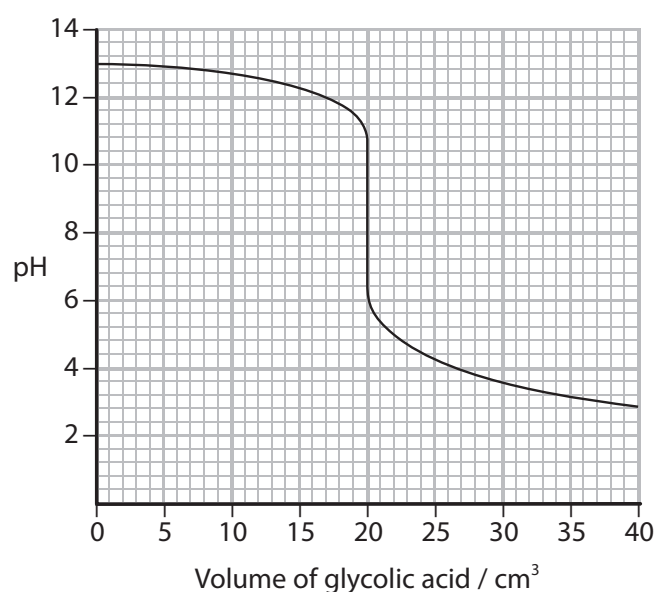
- (b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

(3)



- (c) The titration curve for adding glycolic acid to 25.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide is shown.



- (i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

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- (ii) What is the concentration of this glycolic acid in mol dm^{-3} ?

(1)

- ☐ **A** 0.080
- ☐ **B** 0.100
- ☐ **C** 0.125
- ☐ **D** 0.250

(iii) The pH of the solution containing just sodium glycolate and water is

(1)

- ☐ A 2.8
- ☐ B 6.0
- ☐ C 8.3
- ☐ D 11.0

(d) Glycolic acid has an acid dissociation constant of $1.5 \times 10^{-4} \text{ mol dm}^{-3}$ compared with a value of $1.7 \times 10^{-5} \text{ mol dm}^{-3}$ for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

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(ii) Complete the equation to show the conjugate acid-base pairs that would be produced when pure samples of glycolic acid and ethanoic acid are mixed.

(1)



(Total for Question 8 = 12 marks)



- 10** The progress of the reaction between iodine and propanone with an acid catalyst can be followed in an experiment using a titrimetric method.

Procedure

- Step 1** Mix 25 cm^3 of 1 mol dm^{-3} aqueous propanone with 25 cm^3 of 1 mol dm^{-3} sulfuric acid in a beaker. Both these reactants are in excess.
- Step 2** Start the stop clock as 50 cm^3 of 0.02 mol dm^{-3} iodine solution is added to the beaker. Mix the reactants thoroughly.
- Step 3** Withdraw a 10.0 cm^3 sample of the reaction mixture, using a pipette, and transfer it to a conical flask.
- Step 4** Add a spatula measure of sodium hydrogencarbonate, noting the exact time.
- Step 5** Titrate the iodine present in the 10.0 cm^3 sample with 0.01 mol dm^{-3} sodium thiosulfate solution, using starch indicator.
- Step 6** Continue to withdraw 10.0 cm^3 samples about every two minutes, repeating Steps **4** and **5** with each sample.

- (a) (i) Explain why sodium hydrogencarbonate is added in Step **4**.

(2)

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- (ii) Write the **ionic** equation for the reaction that takes place during Step **4**.
State symbols are not required.

(1)

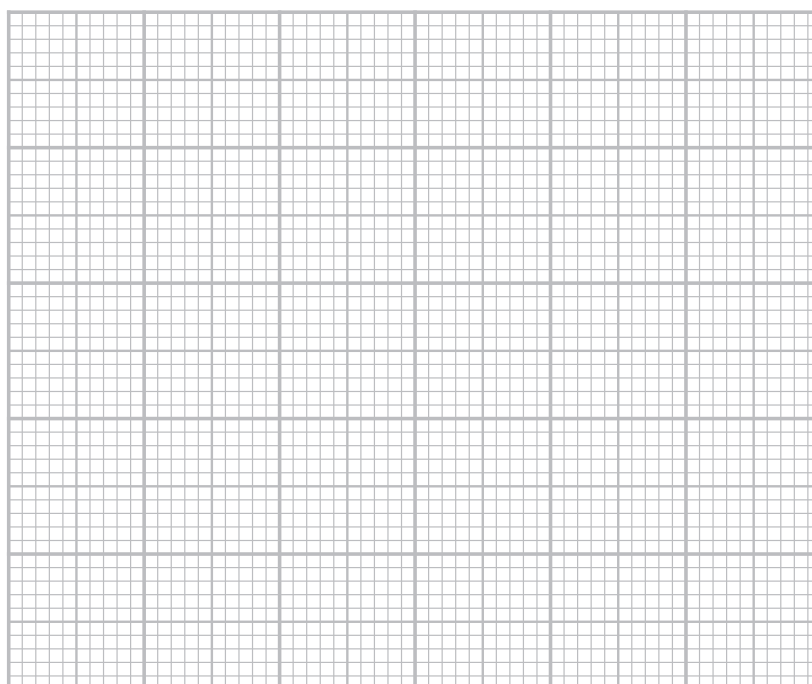


(b) Some data from the experiment are shown.

Time sodium hydrogencarbonate is added / min	2.0	5.0	6.5	8.0	10.5	12.0
Volume of sodium thiosulfate / cm ³	19.2	15.5	14.0	12.1	9.5	7.2

- (i) Plot a graph of the volume of sodium thiosulfate against the time the sodium hydrogencarbonate is added.

(2)



- (ii) Explain how the graph of volume of thiosulfate against time confirms the reaction is zero order with respect to iodine, I_2 .

(3)

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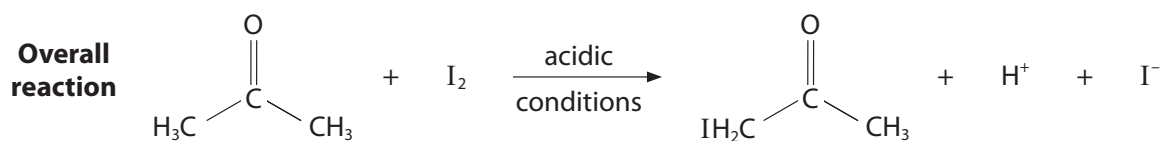
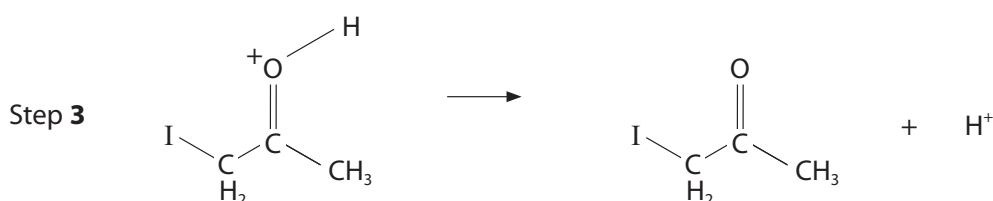
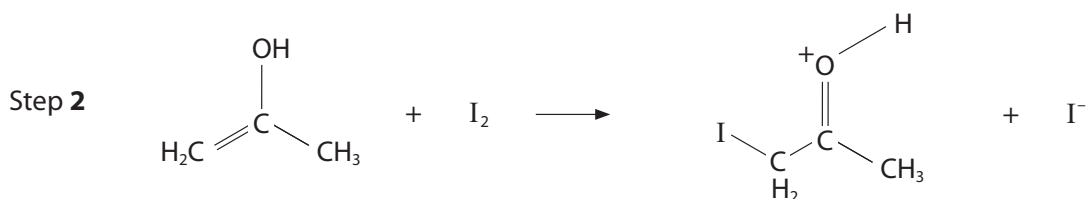
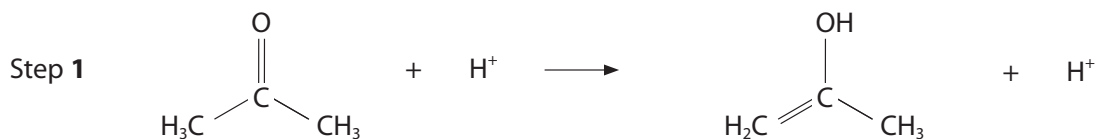
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(c) The overall rate equation for the reaction is $\text{rate} = k[\text{H}^+(\text{aq})][\text{CH}_3\text{COCH}_3(\text{aq})]$.

A student researching the mechanism for the reaction found this example.



(i) Predict which of the three steps is the rate-determining step.
Justify your answer.

(2)

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(ii) The student stated that

‘The hydrogen ions cannot be acting as a catalyst.

One hydrogen ion is a reactant in Step 1 but two hydrogen ions are formed as products in Steps 1 and 3.’

Explain whether or not this statement is valid.

(2)

(Total for Question 10 = 12 marks)



9 Pineapple juice contains the weak acids citric acid ($\text{C}_6\text{H}_8\text{O}_7$) and ascorbic acid ($\text{C}_6\text{H}_8\text{O}_6$). The amount of each compound in a sample of 150 cm^3 of pineapple juice can be determined by titration.

- (a) Experiment 1 is designed to determine the total amount of acid.
 10.0 cm^3 samples of pineapple juice are transferred to separate conical flasks and titrated with a solution of sodium hydroxide of known concentration.

The total amount of acid in the 150 cm^3 sample of pineapple juice is $8.00 \times 10^{-3}\text{ mol}$.

- (i) Give a reason why methyl orange would **not** be a suitable indicator to use in this titration.

(1)

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- (ii) A student did not notice an air bubble in the tip of the burette **before** carrying out one of their accurate titrations. During this titration, the air bubble escaped.

Explain the effect this mistake would have on the value of this titre.

(2)

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- (b) Experiment 2 is carried out to determine the amount of ascorbic acid ($\text{C}_6\text{H}_8\text{O}_6$) in the pineapple juice.

An outline procedure for this experiment is given.

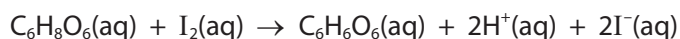
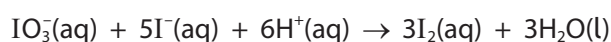
Step 1 5.00 cm^3 of the pineapple juice is added to a conical flask.

Step 2 Deionised water, a small amount of $\text{HCl}(\text{aq})$, a few crystals of potassium iodide, KI , and 3 drops of starch solution are also added to the flask.

Step 3 The contents of the flask are swirled to ensure the KI dissolves fully.

Step 4 The resultant mixture is titrated with a solution of potassium iodate(V), $\text{KIO}_3(\text{aq})$, of concentration $0.00100\text{ mol dm}^{-3}$.

The reactions that take place are



Only the ascorbic acid reacts with the iodine.

- (i) The end-point of the titration is when the starch changes colour.

Explain how this occurs, including the colour change.

(3)

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(ii) The **total** amount of acid in the 150 cm^3 sample is $8.00 \times 10^{-3}\text{ mol}$.

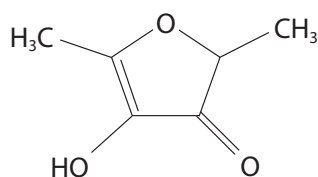
The mean titre in Experiment **2** using 5.00 cm^3 of pineapple juice is 9.50 cm^3 .

Calculate the mass of **citric acid** in the 150 cm^3 sample.

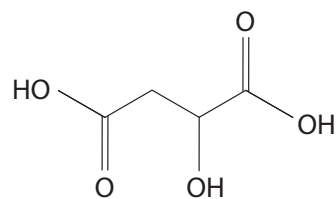
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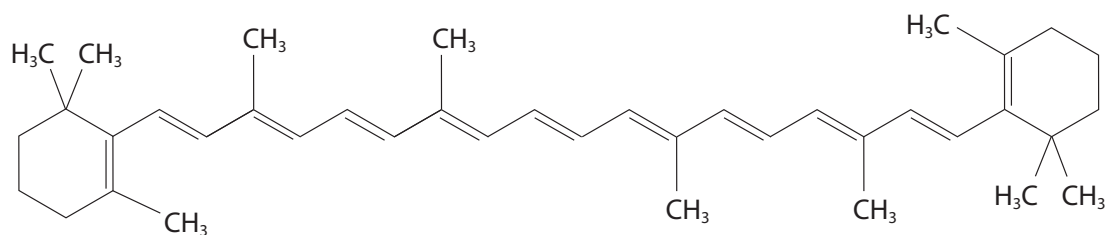
(c) While doing background research for the experiment, a student found that three other compounds, **D**, **E** and **F**, are often present in pineapple juice.



Compound D



Compound E



Compound **F**

Predict which one of these compounds is most likely to affect the result of Experiment 1 and hence predict the effect on the mass of citric acid calculated in (b)(ii).

Justify your answer.

(3)

(Total for Question 9 = 14 marks)

10 Vitamin C has the molecular formula $C_6H_8O_6$.

The label on a bottle of vitamin C tablets stated that a 2.50 g tablet contained 6% of vitamin C by mass. The tablet was analysed to check the accuracy of the label. The procedure involved a series of steps.

(a) **Step 1** Dissolving the tablet.

A 2.50 g vitamin C tablet was crushed and dissolved to make an aqueous solution of volume 250.0 cm^3 .

Describe how to make this solution from the crushed tablet.

(3)

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(b) Step 2 Producing a known amount of iodine.

Iodine was produced by reacting 25.0 cm^3 of $0.0100\text{ mol dm}^{-3}$ potassium iodate with excess potassium iodide and hydrochloric acid in a conical flask.

- (i) Complete the ionic equation for the formation of the iodine from 1 mol of IO_3^- ions.

(1)



- (ii) Show, by calculation, that 7.50×10^{-4} moles of iodine were produced in the flask.

(2)

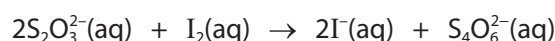
(c) Step 3 Titrating with sodium thiosulfate solution.

10.0 cm^3 of the vitamin C tablet solution from Step 1 was added to the conical flask from Step 2 to react with the iodine produced, as shown in the equation.



The unreacted iodine in the conical flask was titrated with a solution of 0.100 mol dm^{-3} sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.

The mean titre was 14.40 cm^3 .



- (i) State the indicator used in this titration, giving the colour change that would be observed at the end-point.

(2)

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- (ii) Deduce, by calculation, whether the label on the bottle of vitamin C tablets is correct.

(6)

(Total for Question 10 = 14 marks)



10 The progress of the reaction between ethyl ethanoate and water with a hydrochloric acid catalyst can be followed in an experiment using a titrimetric method. An outline procedure is shown.

Step 1 Add 100 cm^3 of 0.500 mol dm^{-3} HCl(aq) to a conical flask.

Step 2 Using a pipette, add 5.0 cm^3 of ethyl ethanoate to the conical flask while mixing.

Step 3 Immediately remove a 5.0 cm^3 sample of the reaction mixture from **Step 2** and add it to a separate conical flask containing crushed ice.

Step 4 Titrate the removed sample using 0.200 mol dm^{-3} NaOH(aq) .

Step 5 Repeat **Steps 3** and **4**, removing 5.0 cm^3 samples every 10 minutes.

Step 6 After 60 minutes, heat the remaining reaction mixture under reflux for 15 minutes.

Step 7 Remove a 5 cm^3 sample of the reaction mixture after completing **Step 6**, titrating this sample with 0.200 mol dm^{-3} NaOH(aq) .

(a) (i) Explain the purpose of the crushed ice in **Step 3**.

(2)

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(ii) Explain why **Step 6** is carried out before the final sample is removed and titrated in **Step 7**.

(2)

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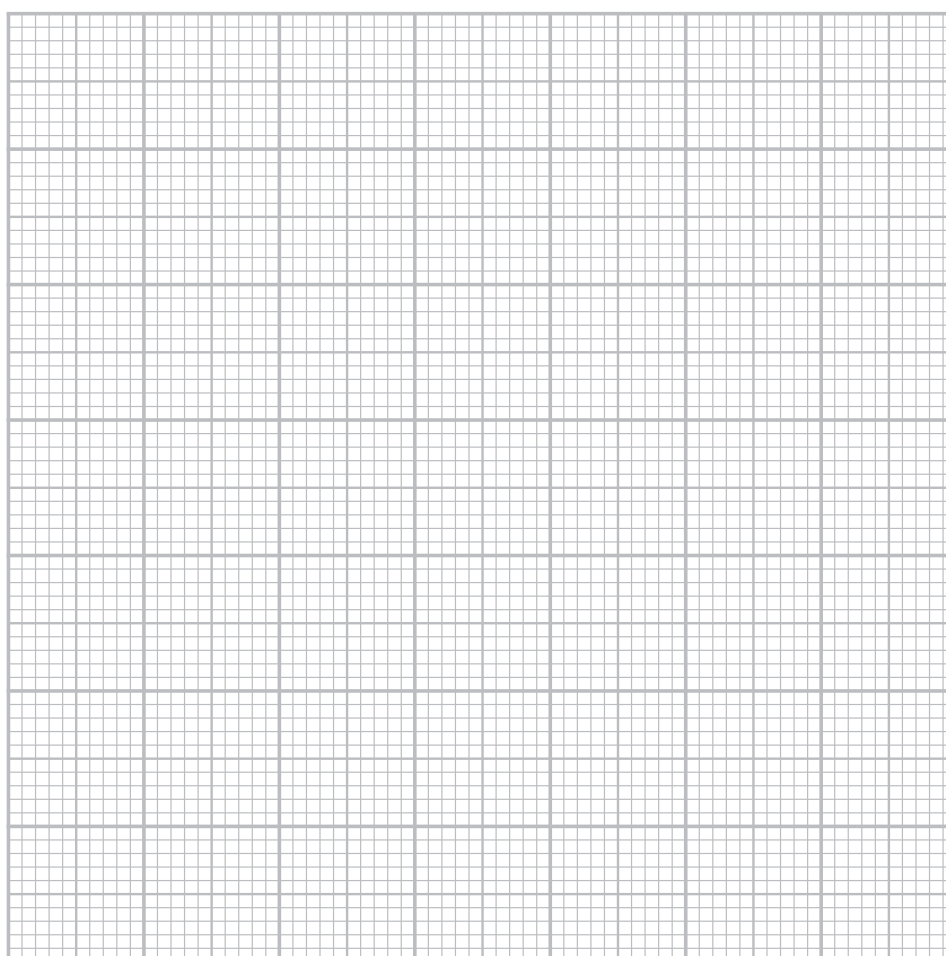
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- (b) Some data from the experiment are shown. V_{final} is the titre volume from Step 7, V_t is the titre volume at time t .

Time reaction sample is added to crushed ice / min	0	10	20	30	40	50	60
$V_{\text{final}} - V_t$ of sodium hydroxide / cm^3	11.60	6.50	3.80	1.80	0.90	0.80	0.80

- (i) Plot a graph of the $V_{\text{final}} - V_t$ of sodium hydroxide against the time the reaction sample is added to the crushed ice.

(3)



- (ii) Explain why $V_{\text{final}} - V_{\text{t}}$ is plotted rather than the concentration of sodium hydroxide solution for each titre.

(2)

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- (iii) Determine two half-lives for the reaction, showing your working on the graph.

(2)

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- (iv) Deduce the order of the reaction, using your answer from (b)(iii) to justify your deduction.

(1)

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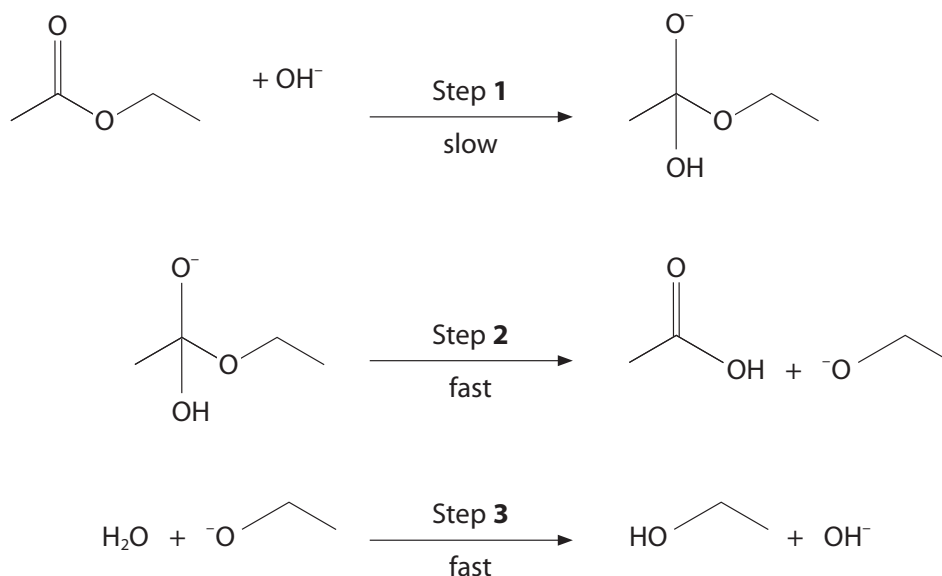
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(c) Ethyl ethanoate can also be hydrolysed under alkaline conditions.

A student researching the mechanism for the reaction found this example.



Deduce a rate equation that is consistent with this reaction mechanism.
Justify your answer.

(2)

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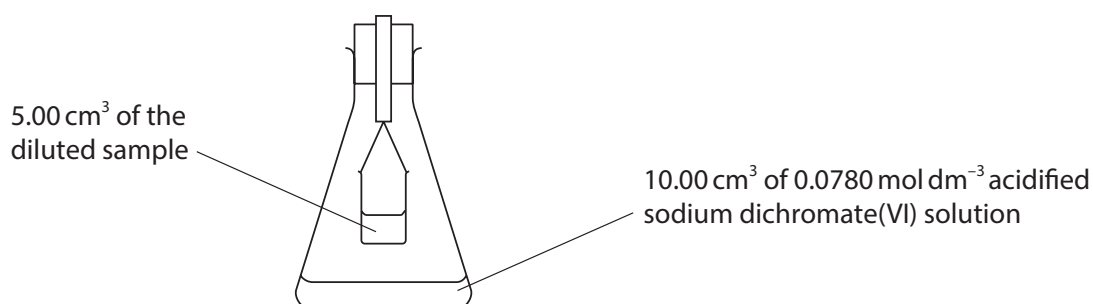
(Total for Question 10 = 14 marks)

- 7 A laboratory technician analysed a sample of an alcoholic drink to determine the concentration of ethanol, in g dm^{-3} .

20.00 cm^3 of the alcoholic drink was added to a 250 cm^3 volumetric flask and made up to the mark with deionised water.

The ethanol in 5.00 cm^3 of the diluted sample was oxidised in the equipment shown.

The sample was suspended in an open beaker in a sealed conical flask over 10.00 cm^3 of acidified sodium dichromate(VI), of concentration 0.0780 mol dm^{-3} .



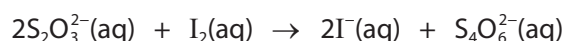
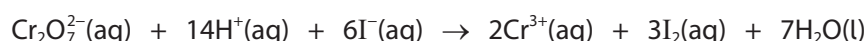
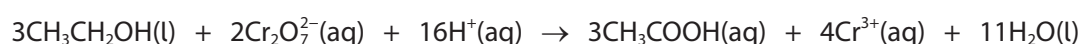
The apparatus was left in a warm place for 24 hours for the acidified sodium dichromate(VI) to oxidise the ethanol.

Excess potassium iodide solution was then added to the **remaining** acidified sodium dichromate(VI) in the conical flask, forming iodine.

All of this iodine was then titrated using 0.0220 mol dm^{-3} sodium thiosulfate solution, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$.

The volume of $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ required in the titration was 32.70 cm^3 .

The equations for the reactions that take place during the experiment are shown.



- (a) Explain why the apparatus was left in a **warm** room and for **24 hours**.

(2)

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(b) (i) Calculate the number of moles of ethanol in 5 cm^3 of the **diluted** drink.

(5)

(ii) Calculate the concentration of ethanol in the alcoholic drink in g dm^{-3} .

(3)



(c) It was suggested that the **titration** as described might lead to an unreliable result.

State **two** ways the procedure could be amended to counter this suggestion.

(2)

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(d) Another technician suggested that it was unnecessary to suspend the drink sample above the acidified sodium dichromate(VI) solution and proposed a change to the procedure.

The proposal was that the drink sample should be mixed with the acidified sodium dichromate(VI) solution and then heated under reflux to allow the ethanol to be oxidised.

Give **one** reason to support this change and **one** reason to leave the method unchanged. In each case justify your answer.

(2)

Reason to support this change

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Reason to leave the method unchanged

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(Total for Question 7 = 14 marks)



- 9 Acidity in wine is mainly due to the dicarboxylic acid tartaric acid, $C_4H_6O_6$.

Sulfur dioxide is added to wine as an antioxidant, to prevent the colour and flavour of the wine from deteriorating. It also inhibits the growth of bacteria.

The concentration of tartaric acid and the concentration of sulfur dioxide present in wine can both be determined by titrations.

- (a) The procedure to find the total amount of tartaric acid in a white wine is shown.

Step 1 Pipette a 20.0 cm^3 sample of the wine into a conical flask.

Step 2 Add anti-bumping granules to the flask, and then place it on a preheated hot plate.

Step 3 Boil the sample to remove any dissolved gases and allow it to cool.

Step 4 Use 0.100 mol dm^{-3} sodium hydroxide solution, NaOH(aq) , in a burette to titrate the sample using a suitable indicator.

- (i) State a precaution you would take in carrying out Step 3.
Justify your answer.

(2)

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- (ii) Explain what effect the omission of Step 3 would have on the titre.

(2)

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(iii) A mean titre of 20.60 cm^3 was obtained.

Calculate the concentration, in g dm^{-3} , of tartaric acid in the white wine.



(3)

(iv) A student carrying out the experiment forgot to remove an air bubble from the tip of the burette **before** carrying out a titration. During the titration, the air bubble escaped.

Explain the effect this mistake would have on the value of this titre.

(2)

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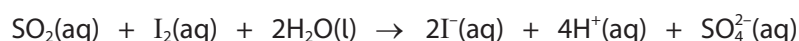
(b) A procedure to find the amount of sulfur dioxide, SO_2 , in a wine is shown.

Step 1 50.0 cm^3 of a white wine is added to a conical flask containing 5 cm^3 of dilute sulfuric acid and a few drops of starch indicator.

Step 2 A spatula measure of sodium hydrogencarbonate is then added to reduce the loss of sulfur dioxide from the flask.

Step 3 The contents of the flask are titrated rapidly using $0.0100\text{ mol dm}^{-3}$ iodine solution, $\text{I}_2(\text{aq})$.

The equation for the reaction that takes place is shown.



(i) A student carrying out the experiment obtained a titre of 11.80 cm^3 .
The maximum permitted level of sulfur dioxide in white wine in the UK is 200 mg dm^{-3} .

Show by calculation that the concentration of sulfur dioxide in the white wine is below the permitted maximum.

(4)



- (ii) Explain how the addition of sodium hydrogencarbonate in Step 2 reduces the loss of sulfur dioxide from the flask.

(2)

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(Total for Question 9 = 15 marks)



- 6 A student carried out an investigation to determine the value of x in hydrated magnesium nitrate(III), $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$, using three different methods.

Method 1

- The student prepared an aqueous solution by dissolving 1.15 g of $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$ in distilled water, making up the solution to 250.0 cm^3 in a volumetric flask and shaking the mixture.
- The student titrated this solution against 25.0 cm^3 portions of an acidified solution of $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), $\text{KMnO}_4(\text{aq})$.

Method 2

- The student mixed a solution of $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$ with an excess of aqueous sodium carbonate solution, $\text{Na}_2\text{CO}_3(\text{aq})$.
- The student obtained a precipitate of magnesium carbonate, $\text{MgCO}_3(\text{s})$, and determined the mass of this precipitate.

Method 3

- The student heated a known mass of $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}(\text{s})$.
- The student determined the mass of the anhydrous residue formed.



Method 1 – Titration

The student filled the burette with the solution made from $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$.

In each titration

- 25.0 cm^3 of $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4(\text{aq})$ was transferred to a conical flask using a pipette.
- An excess of dilute sulfuric acid was added to the conical flask and the mixture heated.
- $\text{Mg}(\text{NO}_2)_2(\text{aq})$ was added from the burette until the end-point was reached.

The student's titration results are shown in the table (the rough titration results have **not** been included in the table).

Titration number	1	2	3
Final burette reading / cm^3	23.95	48.05	23.85
Initial burette reading / cm^3	0.80	24.50	0.65
Titre / cm^3			
Concordant titres (✓)			
Mean titre / cm^3			

(a) Complete the table.

(2)

(b) Deduce the colour change that the student would see at the end-point in this titration.

(1)

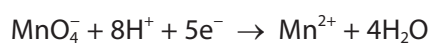
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- (c) In the titration reaction, 2 mol MnO_4^- react with 5 mol NO_2^- .
Calculate the number of moles of NO_2^- in the 250 cm^3 of solution prepared by the student and hence the value of x in $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$.
Give your answer to the nearest whole number.

(5)

- (d) The half-equations for the reaction in the titration are



Use these half-equations to derive the overall ionic equation for the reaction between manganate(VII) and nitrate(III) ions in acidic conditions.
State symbols are not required.

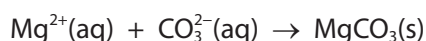
(2)



Method 2 – Precipitation

The student used the following procedure.

- Dissolve a known mass of $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ in distilled water.
- Add an excess of aqueous sodium carbonate solution, $\text{Na}_2\text{CO}_3(\text{aq})$, to obtain a precipitate of magnesium carbonate, $\text{MgCO}_3(\text{s})$.



- Weigh a piece of filter paper.
- Filter the mixture from the above reaction through the pre-weighed filter paper.
- Wash the precipitate of $\text{MgCO}_3(\text{s})$ with distilled water.
- Dry the filter paper and precipitate in a desiccator.
- Reweigh the filter paper and the precipitate.
- Calculate the value of x from the results obtained.

The student found that the value of x calculated using **Method 2** was different from that obtained using **Method 1**. This difference occurred despite having used a pure sample of the hydrated salt and without making any errors in technique during the experiment.

The student found out from a data book that the compound magnesium carbonate is very slightly soluble in water.

- (e) Explain how, if at all, the very slight solubility of magnesium carbonate in water would affect the value calculated for x .

(2)

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- (f) The student planned to obtain any dissolved magnesium carbonate by evaporating the filtrate, and then weighing the residue.

Criticise this student's plan.

(2)

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Method 3 – Thermal decomposition

NOTE: On heating, $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}(\text{s})$ loses its water of crystallisation and **then** undergoes further decomposition to give magnesium oxide, MgO .

The student used the following procedure.

- Weigh an empty crucible.
- Add some $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}(\text{s})$ and then reweigh the crucible plus contents.
- Heat the crucible plus contents and allow to cool.
- Weigh the crucible plus magnesium oxide residue.
- Use these data to calculate a value for x .

The student's results are shown in the table.

Mass of crucible / g	18.02
Mass of crucible + $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$ / g	18.84
Mass of crucible + MgO residue / g	18.27

(g) Identify how the student should ensure that the hydrated salt was fully decomposed.

(1)

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(h) The student carried out an evaluation of the results obtained from **Method 3**

Identify **two** modifications to the method that would enable the student to lower the percentage uncertainty in the measurement of the mass of the solid residue.

(2)

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(Total for Question 6 = 17 marks)



- 7 A group of students analysed a hydrated salt with the formula $\text{KH}_3(\text{C}_2\text{O}_4)_y \cdot z\text{H}_2\text{O}$ where **y** and **z** are whole numbers.

The students carried out experiments to determine the values of **y** and **z**.

- (a) **Experiment 1** – to determine the value of **y**

One student was provided with a $0.0235 \text{ mol dm}^{-3}$ solution of the salt.

25.0 cm^3 portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60°C .

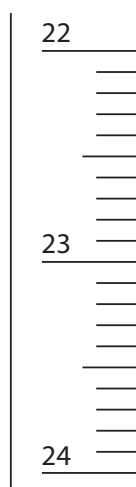
Each portion was titrated with $0.0203 \text{ mol dm}^{-3}$ potassium manganate(VII).

The results of four titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	23.85	47.20	24.05	48.10
Initial burette reading / cm^3	0.00	24.00	0.50	25.00
Titre / cm^3	23.85	23.20	23.55	23.10

- (i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



- (ii) Explain why this student should use a mean titre of 23.15 cm^3 and not 23.43 cm^3 in the calculation.

(2)

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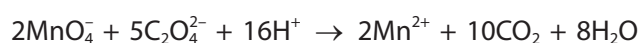


(iii) The uncertainty in each burette reading is $\pm 0.05 \text{ cm}^3$.

Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in **Titration 2**.

(1)

(iv) The equation for the reaction is



Deduce, by calculation, the value of **y**, to the nearest whole number, in the formula $\text{KH}_3(\text{C}_2\text{O}_4)_y \cdot z\text{H}_2\text{O}$.

Use the mean titre of 23.15 cm^3 and other data from **Experiment 1**.

You **must** show your working.

(4)



(b) **Experiment 2** – to determine the value of **z**

Another student wrote an account of the method for this experiment.

A crucible was weighed.

A sample of the hydrated salt was added to the crucible and it was reweighed.

The crucible and salt were heated to remove the water of crystallisation and then allowed to cool.

The crucible and contents were weighed again.

Results

Mass of crucible = 19.56 g

Mass of crucible + $\text{KH}_3(\text{C}_2\text{O}_4)_y \cdot z\text{H}_2\text{O}$ = 22.97 g

Mass of crucible + $\text{KH}_3(\text{C}_2\text{O}_4)_y$ = 22.52 g

- (i) Deduce, by calculation, the value of **z**, to the nearest whole number, in the formula $\text{KH}_3(\text{C}_2\text{O}_4)_y \cdot z\text{H}_2\text{O}$.

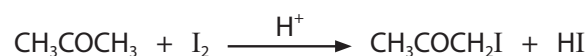
You must use the data from **Experiment 2** and your value of **y** in (a)(iv).

You **must** show your working.

(3)



- 4** This question is about the kinetics of the reaction between iodine and propanone under acidic conditions.
The equation for the reaction is shown.



An experiment is carried out to determine the order of the reaction with respect to iodine.

- Step 1** 50.0 cm³ of 0.0200 mol dm⁻³ iodine solution, I₂(aq), is added from a burette to a conical flask.
- Step 2** 25.0 cm³ of 2.00 mol dm⁻³ sulfuric acid, H₂SO₄(aq), is added to the conical flask using a pipette.
- Step 3** 25.0 cm³ of 2.00 mol dm⁻³ propanone solution, CH₃COCH₃(aq), is added to the conical flask using a pipette.
The flask is swirled and a timer is started.
- Step 4** After 2 minutes, a 10.0 cm³ sample of the reaction mixture is removed and quenched.
- Step 5** The quenched sample is then titrated using 0.0100 mol dm⁻³ sodium thiosulfate solution, Na₂S₂O₃(aq).
- Step 6** Steps **4** and **5** are repeated every two minutes, until six titres have been determined.

- (a) Before carrying out Step **2**, a student noticed droplets of an unknown colourless aqueous solution in the pipette.

Describe how the pipette should be treated before it is used in Step **2**.
Justify your answer.

(2)

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- (b) Samples from the reaction mixture are quenched in Step **4**.

- (i) Explain why quenching is necessary.

(2)

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- (ii) State a compound which can be added to the reaction mixture to quench the reaction.
Include an equation for the reaction that takes place during the quenching process. State symbols are not required.

(2)

Compound

Equation

- (c) One of the products of the reaction, iodopropanone ($\text{CH}_3\text{COCH}_2\text{I}$) is corrosive, strongly irritating to the eyes and can cause breathing difficulties.

Explain why a risk assessment for this experiment says it does **not** have to be carried out in a fume cupboard.

(2)

- (d) Show, by calculating the initial quantities of the reactants involved, that this experiment provides evidence for the order with respect to iodine **only**.

(4)

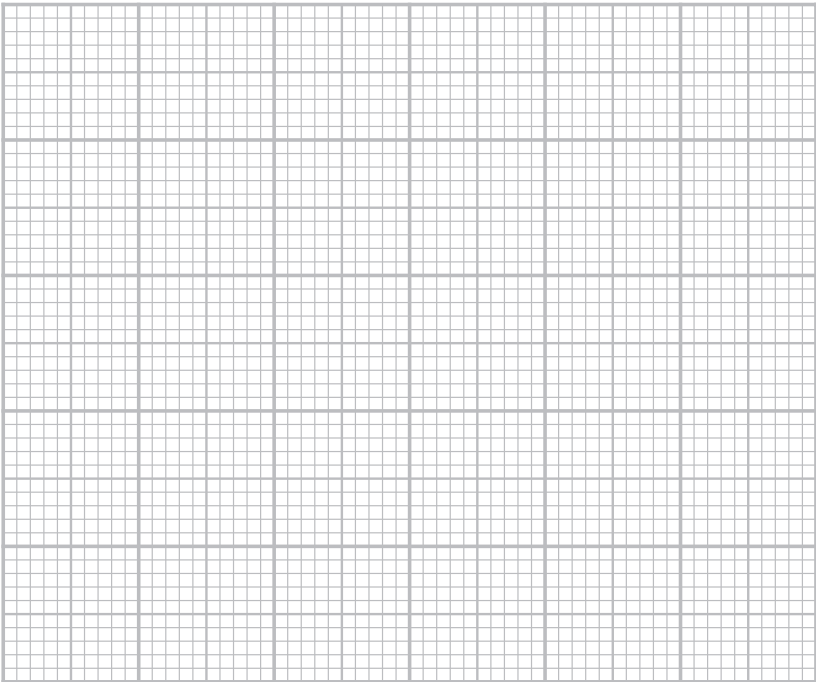


(e) The results of the experiment are shown.

Time / min	Titre / cm ³
2	17.00
4	15.60
6	14.00
8	12.50
10	11.00
12	9.40

(i) Plot a graph of titre against time.

(2)



- (ii) Give the reason why it is not necessary to calculate the concentration of iodine so that the order can be deduced.

(1)

- (iii) Deduce the order with respect to iodine. Justify your answer.

(2)

(Total for Question 4 = 17 marks)

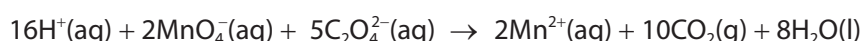


- 8 Tablets containing potassium manganate(VII), KMnO_4 , are dissolved in water forming an antiseptic solution to treat skin conditions. The manufacturers claim that each tablet contains 400 mg of KMnO_4 .

To check the claim, the titration procedure outlined was carried out.

- Five tablets were dissolved in distilled water to make 100.0 cm^3 of solution.
- Some of the KMnO_4 solution was used to fill a burette.
- 25.0 cm^3 of sodium ethanedioate solution, $\text{Na}_2\text{C}_2\text{O}_4(\text{aq})$, of concentration $0.200 \text{ mol dm}^{-3}$, was added to a conical flask and warmed.
- Sulfuric acid, of concentration 2 mol dm^{-3} , was also added to the conical flask.
- The KMnO_4 solution was added to the flask from the burette, until the end-point.

The equation for the reaction between MnO_4^- ions from the KMnO_4 and $\text{C}_2\text{O}_4^{2-}$ ions from the sodium ethanedioate solution is shown.

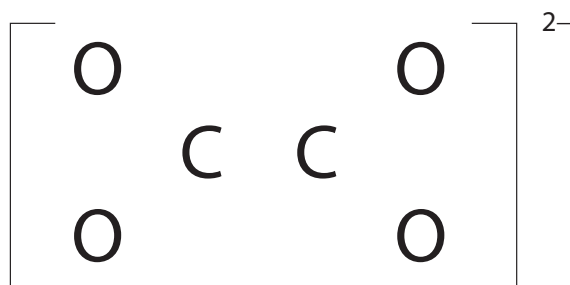


- (a) Give the colour **change** at the end-point of the titration.

(1)

- (b) (i) Complete the dot-and-cross diagram for the ethanedioate ion.
Show the outer electrons only.

(2)



- (ii) Determine the oxidation number of carbon in the ethanedioate ion, $\text{C}_2\text{O}_4^{2-}$.

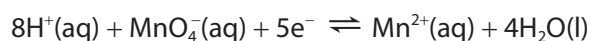
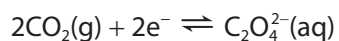
(1)

(c) Give the reason why sulfuric acid was also added to the conical flask.

(1)

(d) This redox reaction could be used in an electrochemical cell.

The cell half-equations are



Write a cell diagram for this cell using the conventional representation.

(2)



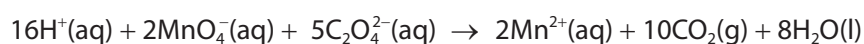
(e) The results of the titration are shown.

Run	Trial	1	2	3
Final volume / cm ³	17.50	34.10	17.20	34.10
Initial volume / cm ³	0.00	17.30	0.00	17.20
Titre / cm ³	17.50		17.20	
Concordant titres (✓)				
Mean titre / cm ³				

(i) Complete the table.

(2)

(ii) The equation for the reaction between MnO_4^- ions from the KMnO_4 and $\text{C}_2\text{O}_4^{2-}$ ions from the sodium ethanedioate solution is shown.



Use this equation and your mean titre from (e)(i) to calculate the mass, in mg, of KMnO_4 in **one** tablet.

Give your answer to an appropriate number of significant figures.

(5)



- (iii) A textbook suggested the conical flask should be heated during the titration, as the reaction between the MnO_4^- ions and the $\text{C}_2\text{O}_4^{2-}$ ions is slow.

Use these electrode potentials and your knowledge of homogeneous catalysis to deduce why the heating is very important at the start of the titration, but less important as the titration proceeds. Justify your answer.
You may include equations in your justification.

Electrode system	$E^\ominus / \text{V}$
$2\text{CO}_2(\text{g}) + 2\text{e}^- \rightleftharpoons \text{C}_2\text{O}_4^{2-}(\text{aq})$	+0.64
$\text{Mn}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq})$	+1.49
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51

(4)

(Total for Question 8 = 18 marks)



3 This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

- (a) A student weighed about 4.00 g of sodium hydroxide pellets and added them to a beaker containing 50 cm³ of deionised water.

The mixture was stirred with a glass rod to dissolve the pellets and to give a homogenous solution.

The solution was poured through a funnel into a 250.0 cm³ volumetric flask and deionised water was added up to the mark and then the flask was shaken.

- (i) Describe how you would ensure that all the sodium hydroxide was transferred to the volumetric flask.

(2)

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- (ii) A student adds deionised water above the mark and shakes the flask.

State why the procedure has to be restarted rather than using a teat pipette to remove the excess water.

(1)

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(b) Two students each cleaned a burette, then poured sodium hydroxide solution into their burettes.

(i) Student 1 used a funnel to pour sodium hydroxide solution into the burette.

Give **two** steps needed before the student takes the initial burette reading.

(2)

(ii) Student 2 cleaned the burette by rinsing it with deionised water immediately before filling it with the sodium hydroxide solution.

Give the effect, if any, on the value of the first titre. Justify your answer.

(1)



- (ii) Complete the table, with a tick (✓) or a cross (X), to show whether or not the indicator would be suitable for use in this titration.

(1)

Indicator	pH range	Tick or Cross
Bromocresol purple	5.2 – 6.8	
Thymol blue	8.0 – 9.6	
Thymolphthalein	8.3 – 10.6	
Alizarin yellow R	10.1 – 13.0	

- (d) Each student used a pipette to measure 25.0 cm^3 of the ethanoic acid solution into four separate conical flasks and added an indicator.

The results of one student's titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	13.00	25.50	37.90	50.00
Initial burette reading / cm^3	0.25	13.00	25.50	37.90
Titre / cm^3				
Concordant titres (✓)				

- (i) Complete the table.

(1)

- (ii) The low titre for titration **4** was queried by the teacher. The student had wanted to refill the burette and continue the titration but had been told the measurement uncertainty would increase if this was done.

Calculate the total percentage measurement uncertainty if the burette had been refilled to 0.00, and then a further 0.30 cm^3 had been added from the burette, to the conical flask.

The measurement uncertainty for each burette reading is $\pm 0.05\text{ cm}^3$.

(1)

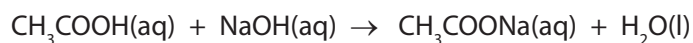


(e) The teacher carried out the experiment and obtained the following results.

Mass of sodium hydroxide used to make 250.0 cm^3 solution = 3.80 g

Volume of ethanoic acid solution = 25.00 cm^3

Mean titre of sodium hydroxide = 11.90 cm^3



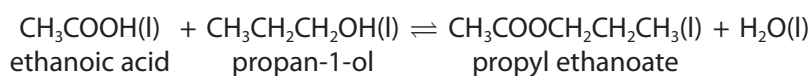
Calculate the concentration of the ethanoic acid solution in g dm^{-3} .
Give your answer to an appropriate number of significant figures.

(5)

(Total for Question 3 = 18 marks)



- 8 This question is about an experiment to determine the equilibrium constant, K_c , for an esterification reaction producing propyl ethanoate. The equation for the reaction is



In an experiment to determine the equilibrium constant, K_c , the following steps were carried out.

- 6.0 cm^3 of ethanoic acid (0.105 mol), 6.0 cm^3 of propan-1-ol (0.080 mol) and 2.0 cm^3 of dilute hydrochloric acid were mixed together in a sealed boiling tube. In this pre-equilibrium mixture, there is 0.111 mol of water
- The mixture was left for one week, at room temperature and pressure, to reach equilibrium
- The equilibrium mixture and washings were transferred to a volumetric flask and the solution made up to exactly 250.0 cm^3 using distilled water
- 25.0 cm^3 samples of the **diluted** equilibrium mixture were titrated with a solution of sodium hydroxide, concentration 0.200 mol dm^{-3} , using phenolphthalein as the indicator
- The mean titre was 23.60 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution.

(a) State the role of the hydrochloric acid in the esterification reaction.

(1)

(b) (i) Calculate the total amount, in moles, of acid present in the **volumetric flask** in the equilibrium mixture.

(2)



- (ii) The 2.0 cm^3 of dilute hydrochloric acid contained 0.00400 mol of $\text{H}^+(\text{aq})$ ions. Use this and your answer to part (b)(i) to calculate the amount, in moles, of ethanoic acid present in the equilibrium mixture.

(1)

- (c) (i) The initial mixture in the boiling tube contained 0.105 mol of ethanoic acid. Use your answer to (b)(ii) to calculate the amount, in moles, of ethanoic acid that reacted to form the ester in the equilibrium mixture.

(1)

- (ii) Use information given in the method, and your answer to (c)(i), to calculate the amounts, in moles, of propan-1-ol, propyl ethanoate and water that are present in the equilibrium mixture.

(3)

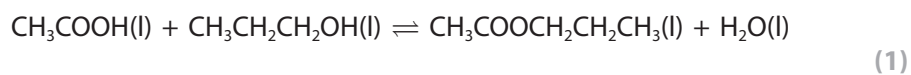
Moles of propan-1-ol at equilibrium.....

Moles of propyl ethanoate at equilibrium.....

Moles of water at equilibrium.....



(d) (i) Write the expression for the equilibrium constant, K_c , for this reaction.



(ii) Explain why it is possible, in this case, to calculate K_c using equilibrium amounts in moles, rather than equilibrium concentrations.

(2)

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.....

.....

(iii) Calculate the value of K_c .

Give your answer to an appropriate number of significant figures.

(2)



- (e) The pink colour of the phenolphthalein fades after the end-point of the titration has been reached.

Give a possible explanation for this observation.

(2)

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- (f) Explain what you could do to confirm that one week is sufficient time for the mixture to reach equilibrium.

(2)

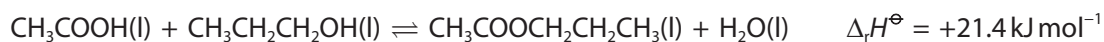
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- (g) A student repeated the experiment, but left the mixture in a water bath at 40 °C until equilibrium was reached.



Deduce the effect, if any, on this student's value for K_c compared with that obtained in part (d)(iii).

(2)

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(Total for Question 8 = 19 marks)



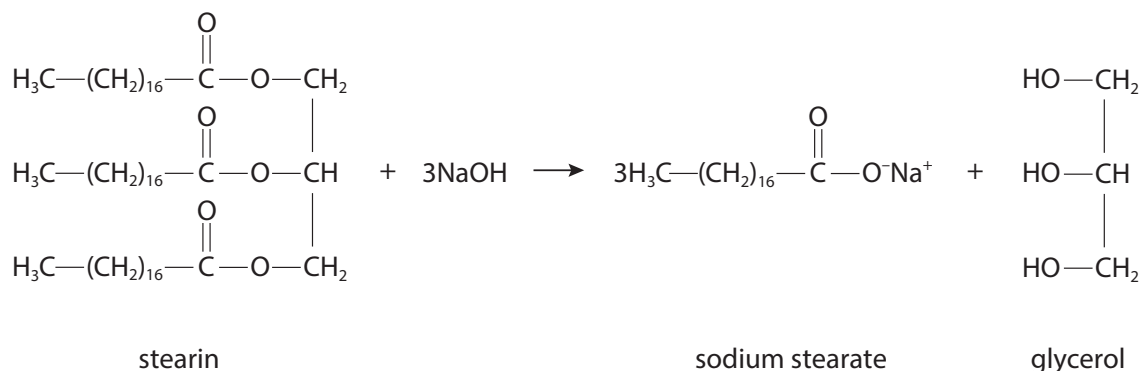
SUB-TOPIC 5(d)

YIELD, ATOM ECONOMY AND UNCERTAINTIES

3 questions in this sub-topic · 30 marks · lowest tariff first



- 3 Sodium stearate is a constituent of soap and can be made from the hydrolysis of stearin as shown.



- (a) What is the atom economy, by mass, for the production of sodium stearate in this reaction?

Substance	stearin	sodium hydroxide	sodium stearate	glycerol
Molar mass / g mol ⁻¹	890	40	306	92

(1)

- ☐ A 32.9%
- ☐ B 34.4%
- ☐ C 90.9%
- ☐ D 98.7%

- (b) What is the IUPAC name for glycerol?

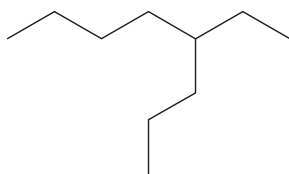
(1)

- ☐ A 1,2,3-trihydroxypropane
- ☐ B propanetriol
- ☐ C 2,3-dihydroxypropan-1-ol
- ☐ D propane-1,2,3-triol

(Total for Question 3 = 2 marks)

2 This question is about alkanes and their reactions.

(a) What is the IUPAC name for this alkane?



(1)

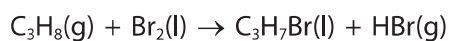
- ☐ A 4-ethyloctane
- ☐ B 5-ethyloctane
- ☐ C 3-propylheptane
- ☐ D 5-propylheptane

(b) What is the name of the process that could be used to produce propane, C_3H_8 , from decane, $C_{10}H_{22}$?

(1)

- ☐ A substitution
- ☐ B reforming
- ☐ C fractional distillation
- ☐ D cracking

(c) A student researched the reaction of propane with bromine and found that the reaction could be used to make 1-bromopropane.



(i) The first step of the reaction involves

(1)

- ☐ A heterolytic bond fission to form free radicals
- ☐ B heterolytic bond fission to form ions
- ☐ C homolytic bond fission to form free radicals
- ☐ D homolytic bond fission to form ions

- (ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (c).

(2)

- (iii) A source from the internet gave the percentage yield for this reaction as 31.0%. The best explanation for the low percentage yield of 1-bromopropane in this reaction is

(1)

- ☐ **A** bromine is very unreactive
- ☐ **B** a gaseous reactant always gives a low yield
- ☐ **C** the reaction is very slow
- ☐ **D** the reaction produces a mixture of organic products

- (iv) Calculate the volume of propane, in dm^3 , measured at room temperature and pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.

Give your answer to an appropriate number of significant figures.

[Molar gas volume at r.t.p. = $24.0 \text{ dm}^3 \text{ mol}^{-1}$]

(3)

(Total for Question 2 = 9 marks)



- 7 Hardness in water is measured in terms of the concentration of dissolved calcium compounds.

Titration experiments can be carried out to determine the hardness of a water sample.

- (a) A pipette is used to measure a 50.0 cm^3 water sample for titration.

- (i) Describe how to remove an air bubble from the tip of the pipette.

(1)

- (ii) Calculate the **maximum** volume that would be obtained by using a 25.0 cm^3 pipette twice to measure a total volume of 50.0 cm^3 .
The uncertainty in each 25.0 cm^3 pipette measurement is $\pm 0.04\text{ cm}^3$.

(1)

- (iii) Compare the percentage uncertainty in using a 25.0 cm^3 pipette twice with using a 50.0 cm^3 pipette once to measure 50.0 cm^3 of water.
The uncertainty in the 50.0 cm^3 pipette measurement is $\pm 0.05\text{ cm}^3$.

(2)



(b) About 2 cm^3 of a pH 10 buffer is added to each 50.0 cm^3 water sample.

- (i) State whether or not a 100 cm^3 measuring cylinder is suitable to measure this volume of buffer solution. Justify your answer.

(1)

- (ii) The pH 10 buffer can be made by adding solid ammonium chloride to an aqueous solution of ammonia of concentration 18.1 mol dm^{-3} .

The relevant equation is



$$K_a = 5.62 \times 10^{-10} \text{ mol dm}^{-3}$$

Calculate the mass of ammonium chloride that must be added to 100 cm^3 of ammonia solution to make the pH 10 buffer.

Assume that there is no change in the volume on the addition of ammonium chloride.

(4)



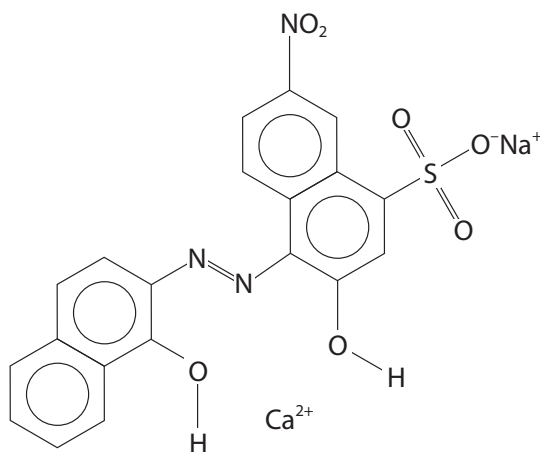
(iii) State a necessary laboratory precaution, other than wearing a laboratory coat, gloves and goggles, that must be taken when using concentrated ammonia.

(1)

(c) The Eriochrome Black T indicator used in this titration forms an octahedral complex with the calcium ions in the water sample. The structure of Eriochrome Black T is shown with a calcium ion.

(i) Complete the diagram to show how Eriochrome Black T forms three dative covalent or coordinate bonds with the calcium ion.

(1)



(ii) State the number of water molecules needed to complete this complex.

(1)

(d) There are two types of water hardness:

temporary hardness which is removed by boiling as a precipitate forms,
permanent hardness which is unaffected by boiling.

Levels of water hardness are expressed as the concentration of calcium ions in mg dm^{-3} .

A student carried out a series of experiments to determine the hardness of a sample of water. 50.0 cm^3 samples of the water were titrated with EDTA. Further 50.0 cm^3 samples of water were taken after boiling and then titrated with EDTA.

(i) Name the process needed before titrating the sample of boiled water.

(1)

(ii) The mean titre of $0.0100 \text{ mol dm}^{-3} \text{ EDTA}^{4-}$ with a 50.0 cm^3 water sample before boiling was 12.80 cm^3 .

After boiling the mean titre was 5.15 cm^3 .

There is a 1 : 1 ratio in the reaction between EDTA^{4-} ions and Ca^{2+} ions.

Calculate, in this water, the levels of permanent and temporary hardness in mg dm^{-3} of calcium ions.

(6)

(Total for Question 7 = 19 marks)



MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Answer	Additional Guidance	Mark								
2(a)	A description that makes reference to the following points: - reagent - observation	<u>Examples of reagents and observations</u> <table><tr><th>Reagent</th><th>Observation</th></tr><tr><td>any carbonate / NaHCO_3 / KHCO_3 (added to aqueous acid)</td><td>effervescence / fizzing / bubbles / gas evolved that turns limewater milky</td></tr><tr><td>magnesium (added to aqueous acid)</td><td>effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint</td></tr><tr><td>alcohol and (concentrated) H_2SO_4 / HCl / H^+</td><td>characteristic smell (of an ester)</td></tr></table> Allow names or formulae for reagents but if both are given, both must be correct Ignore conditions e.g. heat Do not award PCl_5 / Na If more than one test is given, penalise any incorrect tests	Reagent	Observation	any carbonate / NaHCO_3 / KHCO_3 (added to aqueous acid)	effervescence / fizzing / bubbles / gas evolved that turns limewater milky	magnesium (added to aqueous acid)	effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint	alcohol and (concentrated) H_2SO_4 / HCl / H^+	characteristic smell (of an ester)	(2)
Reagent	Observation										
any carbonate / NaHCO_3 / KHCO_3 (added to aqueous acid)	effervescence / fizzing / bubbles / gas evolved that turns limewater milky										
magnesium (added to aqueous acid)	effervescence / fizzing / bubbles / gas evolved that gives a pop with a lighted splint										
alcohol and (concentrated) H_2SO_4 / HCl / H^+	characteristic smell (of an ester)										



Question Number	Answer	Additional Guidance	Mark														
2(b)	A description that makes reference to two of the following points: - reagent - corresponding observation	<u>Examples of reagents and observations</u> <table><thead><tr><th>Reagent</th><th>Observation</th></tr></thead><tbody><tr><td>bromine water Allow bromine (in an organic solvent)</td><td>orange / yellow / brown solution goes colourless Allow bromine water is decolourised</td></tr><tr><td>carboxylic acid and (concentrated) H₂SO₄ / HCl / H⁺</td><td>characteristic smell (of an ester)</td></tr><tr><td>acidified potassium manganate(VII) / permanganate</td><td>purple to colourless / decolourised</td></tr><tr><td>alkaline potassium manganate(VII)</td><td>purple to green</td></tr><tr><td>(neutral) potassium manganate(VII)</td><td>purple to brown ppt</td></tr><tr><td>acidified (potassium) dichromate((VI)) (ions)</td><td>orange to green</td></tr></tbody></table> Allow names or formulae for reagents but if both are given, both must be correct Ignore conditions e.g. heat Do not award PCl₅ / Na If more than one test is given, penalise any incorrect tests	Reagent	Observation	bromine water Allow bromine (in an organic solvent)	orange / yellow / brown solution goes colourless Allow bromine water is decolourised	carboxylic acid and (concentrated) H ₂ SO ₄ / HCl / H ⁺	characteristic smell (of an ester)	acidified potassium manganate(VII) / permanganate	purple to colourless / decolourised	alkaline potassium manganate(VII)	purple to green	(neutral) potassium manganate(VII)	purple to brown ppt	acidified (potassium) dichromate((VI)) (ions)	orange to green	(2)
Reagent	Observation																
bromine water Allow bromine (in an organic solvent)	orange / yellow / brown solution goes colourless Allow bromine water is decolourised																
carboxylic acid and (concentrated) H ₂ SO ₄ / HCl / H ⁺	characteristic smell (of an ester)																
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alkaline potassium manganate(VII)	purple to green																
(neutral) potassium manganate(VII)	purple to brown ppt																
acidified (potassium) dichromate((VI)) (ions)	orange to green																



Question Number	Answer	Additional Guidance	Mark
2(c)	- absorbance for A - absorbance for B - absorbance for C (1) (1) (1)	Absorbance Wavenumber range / cm⁻¹ Absorbance expected in infrared spectrum of A but not in B or C 1720 – 1700 Allow 1725 - 1700 Absorbance expected in infrared spectrum of B but not in A or C 1669 – 1645 Absorbance expected in infrared spectrum of C but not in A or B 1740 – 1725 Allow 1740 - 1720 Allow values in reverse order e.g. 1700 – 1720 for A If single values are given instead of a range award (2) for 3 correct values within the ranges and (1) for 2 correct values Do not award a single value that occurs in two ranges i.e 1720-1725 If no other mark is awarded, allow (1) for: A 3300-2500 and C 2900-2820 / 2775-2700 (3)	

(Total for Question 2 = 7 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
3(a)	A synthetic pathway that includes: Conversion to alcohol (aqueous ethanolic) potassium / sodium hydroxide (1) - name or structure of propan-1-ol (1) EITHER ROUTE 1 Conversion to carboxylic acid (oxidise some of the propan-1-ol using) potassium dichromate(VI) and (dilute) sulfuric acid (1) - name or structure of propanoic acid (1) Formation of ester - react propan-1-ol and propanoic acid together and using (concentrated) sulfuric acid (catalyst) (1) PTO for ROUTE 2	Allow names or formulae for reagents but if both are given, both must be correct Allow correct species in unbalanced equations Allow any combination of structural, displayed or skeletal formulae for the intermediates Penalise missing H once only Ignore conditions e.g. heat / reflux Allow hydroxide ions / OH⁻ Ignore concentration Do not award just ethanol / ethanolic Stand alone mark e.g. CH₃CH₂CH₂OH Allow propanol if correct structure shown somewhere Allow acidified potassium dichromate(VI) / Cr₂O₇²⁻ and H⁺ Allow acidified manganate(VII) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. CH₃CH₂COOH Stand alone mark for C₃ compounds Allow (concentrated hydrochloric) acid / H⁺ / H₃O⁺ instead of sulfuric acid Ignore concentration of acid Ignore incorrect structure of ester e.g. with H or O missing	(5)



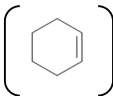
	OR ROUTE 2 Conversion to acyl chloride (oxidise some of the propan-1-ol using) potassium dichromate(VI) and (dilute) sulfuric acid and add phosphorus(V) chloride to propanoic acid (1) - name or structure of propanoyl chloride (1) Formation of ester - react propan-1-ol and propanoyl chloride together (1)	Allow acidified potassium dichromate(VI) / $\text{Cr}_2\text{O}_7^{2-}$ and H^+ Allow acidified manganate(VII) Ignore concentration of acid / formation of aldehyde Do not award hydrochloric acid / HCl Stand alone mark e.g. $\text{CH}_3\text{CH}_2\text{COCl}$ Stand alone mark for C_3 compounds Ignore incorrect structure of ester e.g. with H or O missing	
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Question Number	Acceptable Answers	Additional Guidance	Mark
3(b)	Identifications - structure of alcohol B (1) - structure of ester A (1) Justification - butan-2-ol / $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$ is the only alcohol (with formula $\text{C}_4\text{H}_{10}\text{O}$) that (undergoes elimination and) produces (but-1-ene and) but-2-ene (1)	Allow any combination of structural, displayed or skeletal formulae / correct species in unbalanced equations Allow structures not labelled A and B Penalise missing H once only <u>Examples of identification</u> (B) <pre> H H OH H H — C — C — C — C — H H H H H </pre> Ignore connectivity of the OH group unless horizontal (A) <pre> H H — C — H H — C — C — O — C — C — C — H H H O H H H </pre> Ignore incorrect name for A TE on incorrect alcohol Allow butan-2-ol can form a double bond either side of the C with OH / between the 1st and 2nd carbon atoms and the 2nd and 3rd carbon atoms – this can be shown on diagram / equation Allow OH must be on the 2nd carbon atom / secondary alcohol to form but-1-ene and but-2-ene Allow butan-1-ol gives but-1-ene and 2-methylpropan-1-ol / 2-methylpropan-2-ol gives (2-)methylpropene Allow the other alcohols (with formula $\text{C}_4\text{H}_{10}\text{O}$) do not give but-2-ene	(3)

(Total for Question 3 = 8 marks)

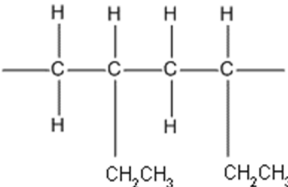


Question number	Answer	Mark
2(a)	The only correct answer is C  <i>A is incorrect because this has molecular formula C₆H₁₂</i> <i>B is incorrect because this has molecular formula C₆H₈</i> <i>D is incorrect because this has molecular formula C₆H₈</i>	(1)

Question number	Answer	Mark
2(b)	The only correct answer is C (2,3-dimethylbut-1-ene) <i>A is incorrect because the longest chain has 4 carbon atoms</i> <i>B is incorrect because the longest chain has 4 carbon atoms</i> <i>D is incorrect because the C=C should have the lowest number</i>	(1)



Question Number	Answer	Additional Guidance	Mark									
2(c)	- product in Reaction 1 - reagent in Reaction 2 - condition in Reaction 2	Example of table <table><tr><th>Reaction</th><th>Reagent and condition</th><th>Product</th></tr><tr><td>1</td><td>(HBr at room temperature)</td><td>$\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}- & \text{C}-\text{Br} \\ & \\ \text{H} & \text{H} \end{array}$</td></tr><tr><td>2</td><td>steam / H₂O(g) and acid / H⁺</td><td>$\left(\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}- & \text{C}-\text{OH} \\ & \\ \text{H} & \text{H} \end{array} \right)$</td></tr></table> (1) Allow structural / skeletal / molecular formula / name for (1-)bromoethane (1) Allow water / H₂O and heat instead of steam (1) Allow specific acid e.g. (concentrated) phosphoric acid / sulfuric acid Ignore any specific temperature and pressure Do not award acid if mention of any reagent other than steam / water e.g. acidified dichromate	Reaction	Reagent and condition	Product	1	(HBr at room temperature)	$\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}- & \text{C}-\text{Br} \\ & \\ \text{H} & \text{H} \end{array}$	2	steam / H ₂ O(g) and acid / H ⁺	$\left(\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}- & \text{C}-\text{OH} \\ & \\ \text{H} & \text{H} \end{array} \right)$	(3)
Reaction	Reagent and condition	Product										
1	(HBr at room temperature)	$\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}- & \text{C}-\text{Br} \\ & \\ \text{H} & \text{H} \end{array}$										
2	steam / H ₂ O(g) and acid / H ⁺	$\left(\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}- & \text{C}-\text{OH} \\ & \\ \text{H} & \text{H} \end{array} \right)$										

Question Number	Answer	Additional Guidance	Mark
2(d)(i)	2 repeat units with extension bonds	<u>Example of two repeat units</u>  The extension bonds can be solid / dotted / dashed Allow C₂H₅ for the side chains Allow ethyl groups on carbon atoms: 1 and 3, 2 and 4, 1 and 4 or 2 and 3 Allow skeletal formula / any combination of structural or displayed formulae Ignore brackets / n Ignore connectivity of vertical CH₂CH₃ groups	(1)

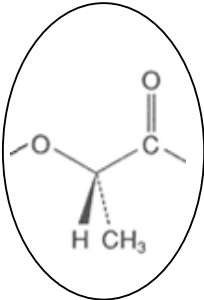
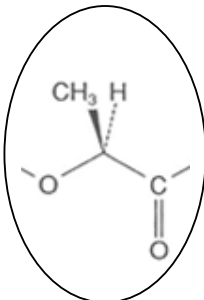
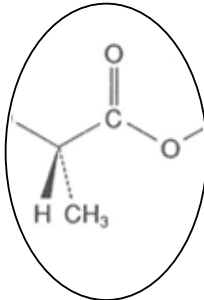
Question Number	Answer	Additional Guidance	Mark
2(d)(ii)	- calculation of moles of but-1-ene (1) - calculation of number of molecules of but-1-ene (1)	<u>Example of calculation</u> moles of but-1-ene = $\frac{70.0}{56.0} = 1.25$ (mol) molecules of but-1-ene = $1.25 \times 6.02 \times 10^{23}$ = 7.525×10^{23} TE on moles but-1-ene Ignore SF except 1 SF Do not award M2 for mass $\times 6.02 \times 10^{23}$ Correct answer with no working scores (2)	(2)

(Total for Question 2 = 8 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: (1st Step) - HCN (and KCN) (1) - Nucleophilic addition (1) $\text{CH}_3\text{CHO} + \text{HCN} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CN}$ (1) (2nd Step) - Any identified (dilute) strong acid / H^+ (1) - Heat (under reflux) / reflux (1) - Hydrolysis (1) $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2\text{O} + \text{H}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NH}_4^+$ or $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NH}_3$ (1)	Ignore references to other conditions / solvent in step 1 Allow HCN and CN^- / H^+ and CN^- / H^+ and KCN or KCN and H_2SO_4 / KCN and HCl or HCN at pH 8 – 9 M1 can be scored for the appearance of HCN in M3 Do not award additional incorrect reaction types e.g. nitrification Allow skeletal formulae in equations M4, 5 & 6 dependent on the formation of any nitrile in step 1 Allow sodium hydroxide followed by acid Do not award conc. acid / just "acidify" / just "acid" Allow warm Do not award additional incorrect reaction types Allow two equations involving NaOH and H^+ Allow $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2\text{O} + \text{HCl} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NH}_4\text{Cl}$	(7)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)(i)	Condensation (polymerisation)	Ignore esterification or addition-elimination Do not award addition	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
2(b)(ii)	Repeat unit circled on diagram as follows:  or 	Allow any repeat unit e.g.  Do not award circle containing more than one repeat unit	(1)

(Total for Question 2 = 9 marks)

Question number	Answer	Mark
5(a)	The only correct answer is D (C₆H₁₄) <i>A is incorrect because this has general formula C_nH_n and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}</i> <i>B is incorrect because this has general formula C_nH_{2n-2} and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}</i> <i>C is incorrect because this has general formula C_nH_{2n} and non-cyclic, saturated hydrocarbons have the general formula C_nH_{2n+2}</i>	(1)

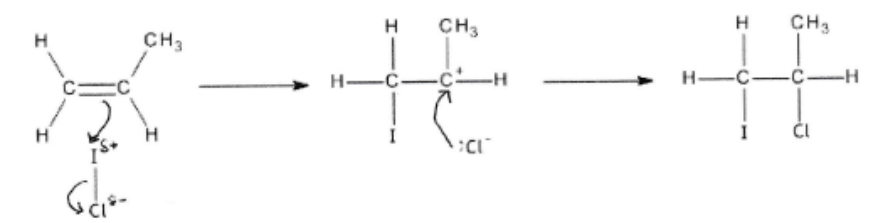
Question number	Answer	Mark
5(b)	The only correct answer is B (3) <i>A is incorrect because the structural isomers of C₅H₁₂ are pentane, 2-methylbutane and 2,2-dimethylpropane</i> <i>C is incorrect because the structural isomers of C₅H₁₂ are pentane, 2-methylbutane and 2,2-dimethylpropane</i> <i>D is incorrect because the structural isomers of C₅H₁₂ are pentane, 2-methylbutane and 2,2-dimethylpropane</i>	(1)

Question number	Answer	Mark
5(c)	The only correct answer is D (16σ bonds and 1π bond) <i>A is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond</i> <i>B is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond</i> <i>C is incorrect because there are 10 σ C-H bonds, 6 C-C σ bonds and 1 C-C π bond</i>	(1)



Question Number	Answer	Mark
5(d)(i)	The only correct answer is A (50 cm³) <i>B is incorrect because this is the increase in volume from 200 cm³ of ethane</i> <i>C is incorrect because this is the volume of CO₂ formed</i> <i>D is incorrect because this is the total volume of CO₂ and H₂O formed</i>	(1)

Question number	Answer	Additional Guidance	Mark
5(d)(ii)	- calculation of x (1) - calculation of y (1) - structure of cyclopentene (1)	<u>Example of calculation</u> (volume of CO₂ = 125 (cm³) so $x = 125/25 = 5$ $(25 + 25(5 + (y/4)) - 75 = 125)$ $y = 8$  Allow the skeletal formula of any cyclic C₅H₈ compound with C=C e.g. a methylcyclobutene TE on x and y for a cyclic hydrocarbon	(3)

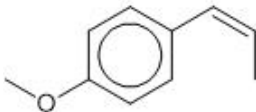
Question Number	Answer	Additional Guidance	Mark
5(e)	- dipole on I-Cl and correct major product (1) - curly arrow from C=C to I and curly arrow from I-Cl to, or just beyond, Cl (1) - intermediate (1) - lone pair on Cl⁻ and curly arrow from lone pair to C⁺ (1)	<u>Example of mechanism</u>  Do not award C^{δ+} on intermediate Allow curly arrow from lone pair to C^{δ+} if penalised in M3 Notes If minor product formed, M2, M3 (with I on other carbon atom) and M4 can score If dipole shows Cl^{δ+} or no dipole shown and Cl joining first, M2 can score for curly arrow from C=C to Cl and curly arrow from Cl-I to, or just beyond, I and M4 can score for lone pair on I⁻ and curly arrow from lone pair to C⁺	(4)

Question Number	Answer	Additional Guidance	Mark
5(f)	- calculation of moles of Br₂ (1) - calculation of moles of limonene (1) - calculation of mass of limonene (1) - calculation of percentage of limonene and answer given to 2 or 3 SF (1)	<u>Example of calculation</u> moles of Br₂ = $\frac{30.6 \times 0.200}{1000} = 0.00612 / 6.12 \times 10^{-3}$ moles of limonene = $\frac{0.00612}{2} = 0.00306 / 3.06 \times 10^{-3}$ TE on moles of Br₂ molar mass of limonene = 136 (g mol⁻¹) and mass of limonene in oil = 0.00306 x 136 = 0.41616 (g) TE on moles of Br₂ percentage of limonene = $\frac{0.41616}{0.500} \times 100$ (= 83.232(%)) = 83/83.2(%) TE on mass of limonene provided answer is less than 100% with 0.500 as denominator Correct answer with no working scores (4)	(4)

(Total for Question 5 = 15 marks)

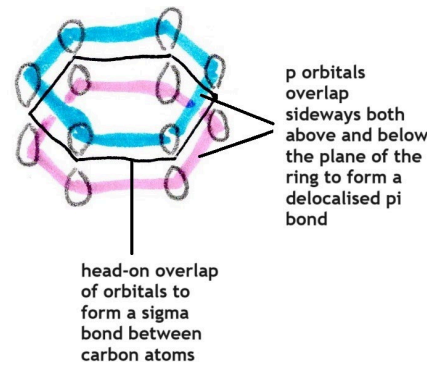


Question Number	Answer	Additional Guidance	Mark
8(a)	$\text{C}_{10}\text{H}_{12}\text{O}$	Accept atoms (and corresponding numbers) in any order Numbers must be sub scripts (and cannot be super scripts)	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)	structure	 Allow Kekulé structure Ignore bond lengths Do not award omission of benzene ring Accept displayed or skeletal formula	(1)

Question Number	Answer	Additional Guidance	Mark
8(c)	An answer that makes reference to the following point: - each carbon atom (in anethole) in the $\text{C}=\text{C}$ group is bonded to two different substituents or - one of the carbon atoms (in estragole) in the $\text{C}=\text{C}$ group is bonded to two hydrogen atoms/same substituents	Allow both carbons of the $\text{C}=\text{C}$ group do not have two different atoms / groups bonded to them Do not allow 'on the same side' Allow functional groups instead of substituents Ignore reference to restricted rotation about $\text{C}=\text{C}$	(1)

Question Number	Answer	Mark
8(d)	The only correct answer is A (acidified potassium manganate(VII)) <i>B is not correct because the nucleophilic hydroxide ions would be repelled by the C=C bond</i> <i>C is not correct because the nucleophilic hydroxide ions would be repelled by the C=C bond</i> <i>D is not correct because a diol is not formed by the addition of steam</i>	(1)

Question Number	Answer	Additional Guidance	Mark
8(e)(i)	A description that makes reference to the following points: sigma bonds - head on/direct overlap (between orbitals) from neighbouring carbon atoms to form a sigma bond π-bonds (perpendicular) p orbitals overlap sideways (to form the π-bonds) - so (p orbital electrons) form a delocalised π system/ring system	Evidence for all marking points may be given in an annotated diagram Allow sp^2 hybrid orbitals overlap to form a sigma bond <u>Example of diagram</u>  head-on overlap of orbitals to form a sigma bond between carbon atoms p orbitals overlap sideways both above and below the plane of the ring to form a delocalised pi bond	(3)

Question Number	Answer	Additional Guidance	Mark
8(e)(ii)	An explanation that makes reference to the following points: Thermodynamic measurement - the enthalpy of hydrogenation for the Kekulé structure would be (three times) greater than that of cyclohexene (1) or if values given (-208 kJ mol^{-1} for benzene and -360 kJ mol^{-1} for Kekulé) (so) in the delocalised model it is more (energetically) stable/is more accurate (1) Physical measurement (X-ray measurements would show that) carbon-carbon bond lengths are different in the Kekulé structure (1) (but) in the delocalised model the bond lengths are all equivalent (1)	Allow use of enthalpy level diagrams for M1 and M2 Allow enthalpy of combustion/hydrogenation for Kekulé structure would be more exothermic than that of benzene Allow enthalpy of formation for Kekulé is more endothermic/less exothermic than of benzene Do not allow reference to less / smaller / lower M2 depends on M1 or near miss, i.e. use of less/smaller/lower Allow reference to forming a regular/perfect hexagon	(4)



Question Number	Answer	Additional Guidance	Mark
8(f)	An answer that makes reference to the following points: - anethole is soluble in ethanol (1) - anethole is less soluble/slightly soluble in water (1) And any one from: (1) - anethole is more attracted to the non-polar part/ethyl of the ethanol molecule than water - anethole forms greater intermolecular/London forces with ethanol than water - structures of anethole and ethanol are more similar (than anethole and water) - anethole forms hydrogen bonds with water less readily (than with ethanol)	Ignore reference to hydrogen bonds Allow anethole is more soluble in ethanol than in water scores M1 and M2 Allow anethole is insoluble in water Or reverse argument (ORA)	(3)

Question Number	Answer	Mark
8(g)	The only correct answer is B (6) <i>A is not correct because there are four non-equivalent carbon atoms in the ring and not three</i> <i>C is not correct because there are four non-equivalent carbon atoms in the ring and not five</i> <i>D is not correct because not all of the carbon atoms in the ring are non-equivalent</i>	(1)

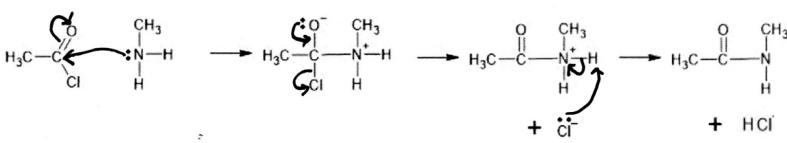
(Total for Question 8 = 15 marks)



Question Number	Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following points: butylamine from a halogenoalkane - equation for making butylamine from a halogenoalkane (1) (conditions of excess) ammonia and alcoholic solvent and/or heat in a sealed tube (1) - from the halogenoalkane the reaction is (nucleophilic) substitution (1) butylamine from butanenitrile - equation for making butylamine from butanenitrile (1) - LiAlH₄ and (conditions of dry) ether (1) - from the nitrile the reaction is reduction And any one from: - from the halogenoalkane secondary and tertiary amines will also be produced (so the yield is low) (1) - greater atom economy from the nitrile - only one product from the nitrile	Allow structural, displayed or skeletal throughout Reagent can be awarded from equations Penalise incorrect chain length once only Example of equation $\text{C}_4\text{H}_9\text{Br} + 2\text{NH}_3 \rightarrow \text{C}_4\text{H}_9\text{NH}_2 + \text{NH}_4\text{Br}$ Allow $\text{C}_4\text{H}_9\text{Br} + \text{NH}_3 \rightarrow \text{C}_4\text{H}_9\text{NH}_2 + \text{HBr}$ Accept heat under pressure Do not award reference to reflux Do not award electrophilic Example of equation $\text{C}_3\text{H}_7\text{CN} + 4[\text{H}] \rightarrow \text{C}_4\text{H}_9\text{NH}_2$ Accept hydrogen gas and Ni / Pd / Pt with $\text{C}_3\text{H}_7\text{CN} + 2\text{H}_2 \rightarrow \text{C}_4\text{H}_9\text{NH}_2$ Allow redox for reduction Allow hydrogenation Allow from the halogenoalkane heating in a sealed tube is difficult in practice Allow hard to exclude water when using LiAlH₄	(7)

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	An answer that makes reference to the following points: - correct organic species in equation (1) - remaining species and balancing of equation (1) (conditions) - tin / Sn and (concentrated) HCl and heat under reflux (1)	Example of equation  Allow Kekulé structures Allow 6H₂ for 12[H] Do not allow molecular formulae for M1 Look for evidence of conditions in the equation Do not award dilute Ignore addition of NaOH to neutralise ammonium salt Allow heat or reflux Note allow other reducing reagents which would work, such as Zinc and HCl	(3)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to the following points: (a base) is a proton acceptor/is a lone pair donor (1) - propane-1,3-diamine has a lower pK_b and so is a stronger base (1) or benzene-1,3-diamine has a higher pK_b so is a weaker base Lone pair of electrons on Nitrogen in benzene-1,3-diamine are delocalised (with the ring of electrons/ π system) (1) - So lone pair less readily available in benzene-1,3-diamine (1)	Ignore reference to the two amine groups Allow correct conversion to K_b with correct comment about base strength Allow Alkyl groups in propane-1,3-diamine are electron releasing. Do not award nitrogen lone pair donated into the benzene ring Penalise omission of 'lone pair' once only If no other mark scored then allow (1) for: Correct identification of the stronger base (1) or any reference to a (lone) pair of electrons on nitrogen atom (1) or availability of (lone) pair determines basicity scores (1)	(4)

Question Number	Answer	Additional Guidance	Mark
7(c)	An answer that makes reference to the following points: All 6 curly arrows correct scores (3) 4 or 5 curly arrows scores (2) 2 or 3 curly arrows scores (1)	<u>Example of curly arrows in mechanism</u>  Allow lone pair on chloride ion to attack either hydrogen (with the correct hydrogen removed) If dipoles given, must be correct Penalise half headed arrows once only If additional arrows added, subtract 1 for each incorrect arrow above the expected 6 arrows from the 'arrow total' before calculating score	(3)

(Total for Question 7 = 17 marks)

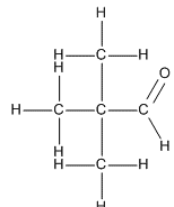
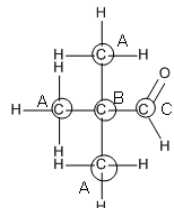
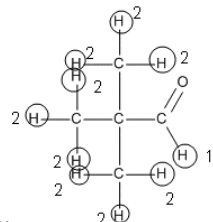
Question Number	Answer	Additional Guidance	Mark
8 (a)	A description that makes reference to the following points: (add a solution of) iodine and alkali / sodium hydroxide / potassium hydroxide / hydroxide ions (and warm) (1) or (add a solution of) potassium iodide in sodium chlorate(I) (and warm) (only) pentan-2-one give a (pale) yellow precipitate / ppt(e) / solid (1)	Allow names or formulae but if both are given, both must be correct Stand alone mark Allow antiseptic smell Ignore observation for pentan-3-one unless also stated that it gives a yellow precipitate	(2)



Question Number	Answer	Additional Guidance	Mark
8(b)(i)	An answer that makes reference to the following points: - curly arrow from lone pair on C of CN^- to C of ketone group (1) - curly arrow from $\text{C}=\text{O}$ to, or just beyond, O (1) - intermediate (1) - curly arrow from lone pair on O^- to H and curly arrow from H-CN bond to anywhere on CN (1)	Example of mechanism: Allow C_3H_7 and CH_3 for propyl and methyl groups Allow CN bond displayed Ignore correct dipoles, penalise an incorrect dipole once only Do not award M3 if C^+ is shown on intermediate For M4, allow curly arrow from lone pair on O^- to H^+ ion / H_2O molecule Penalise incorrect ketone once only in M3 intermediate Penalise curly arrow from -ve charge instead of lone pair once only	(4)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An explanation that makes reference to the following points: • pentan-2-one / ketone is planar about the carbonyl carbon (1) • so the CN^- / nucleophile attacks (equally) from above and below / either side (of the plane) (1)	Allow bonds about $\text{C}=\text{O}$ are (trigonal) planar or the carbonyl carbon is (trigonal) planar Do not award planar molecule / reference to planar intermediate / ion Do not award multiple directions	(2)



Question Number	Answer	Additional Guidance	Mark
8(c)	An answer that makes reference to the following points: - displayed formula of aldehyde (1) - three different carbon environments indicated (1) - two different proton environments indicated (1) - no splitting as there are no hydrogens on the adjacent carbon atom(s) (1)	Example of displayed formula:  Allow CH₃ groups but aldehyde group must be displayed Example of three carbon environments:   Example of two proton environments: Stand alone mark	(4)

Question Number	Acceptable Answers	Additional Guidance	Mark												
8(d)*	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning.	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5–4	3														
3–2	2														
1	1														
0	0														



		Number of marks awarded for structure of answer and sustained line of reasoning		In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.	
	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2			
	Answer is partially structured with some linkages and lines of reasoning.	1			
	Answer has no linkages between points and is unstructured.	0			
	Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning				



	Indicative content • IP1 Reagents and conditions for oxidation – acidified potassium dichromate(VI) / $\text{K}_2\text{Cr}_2\text{O}_7$ and $\text{H}^+/\text{H}_2\text{SO}_4$ or acidified sodium dichromate(VI) / $\text{Na}_2\text{Cr}_2\text{O}_7$ and $\text{H}^+/\text{H}_2\text{SO}_4$ or Fehling's solution / Benedict's solution or Tollens' reagent / ammoniacal silver nitrate / $\text{Ag}(\text{NH}_3)^{2+}$ • IP2 Oxidation of aldehyde – structure of pentanoic acid • IP3 Oxidation of ketone – pentan-3-one / ketone is not (easily) oxidised • IP4 Reagents and conditions for reduction – lithium tetrahydridoaluminate(III) / lithium aluminium hydride and dry ether / ethoxyethane (followed by a dilute acid) or sodium tetrahydridoborate(III) / sodium borohydride and aqueous / methanol solution (followed by a dilute acid) • IP5 Reduction of aldehyde – structure of pentan-1-ol • IP6 Reduction of ketone – structure of pentan-3-ol	Reagents - Allow names or formulae but if both are given, both must be correct Products - Allow any combination of displayed and structural formulae / skeletal formulae Allow C_4H_9 / C_3H_7 for the alkyl groups Allow acidified dichromate(VI) ions / $\text{Cr}_2\text{O}_7^{2-}$ and $\text{H}^+/\text{H}_2\text{SO}_4$ Allow acidified manganate(VII) ions / MnO_4^- and $\text{H}^+/\text{H}_2\text{SO}_4$ Ignore reference to heat Do not award just Cu^{2+} for Fehling's / Benedict's $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH}$ Allow lithal Ignore hydrogen and platinum (catalyst) Ignore reference to heat $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$	
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(Total for Question 8 = 18 marks)



Question Number	Answer	Mark
1	The only correct answer is D (3.6×10^{23}) <i>A is not correct because the number of moles of $(\text{NH}_4)_2\text{SO}_4$ has been divided by 3, rather than multiplied by 3</i> <i>B is not correct because it is the number of SO_4^{2-} ions</i> <i>C is not correct because it is the number of NH_4^+ ions</i>	(1)

Question Number	Answer	Mark
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Question Number	Answer	Mark
2	The only correct answer is C (31.2 dm^3) <i>A is not correct because the answer assumes a 1:1 ratio of butane to oxygen</i> <i>B is not correct because the answer assumes a 1:2 ratio of butane to oxygen</i> <i>D is not correct because the answer assumes a 1:13 ratio of butane to oxygen</i>	(1)



Question Number	Answer	Additional Guidance	Mark
4(a)(i)	- conversion of pressure, volume and temperature to correct units (1) - rearrangement of ideal gas equation so $n = PV \div RT$ and calculation of n (1) - conversion of answer into mass to 2/3 SF (1)	<u>Example of calculation:</u> 207kPa = 207 000 Pa 8.98 dm³ = 0.00898 m³, 20°C = 293 K $n = \frac{207\,000 \times 0.00898}{8.31 \times 293} =$ = 0.7634... = 0.7634... x 28 = 21.37647.. = 21.4 / 21 (g) Correct answer with no working scores 3 TE on both parts of the calculation	(3)
Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	The temperature increase will result in an increase in pressure because p is (directly) proportional to T (at constant volume and moles of gas)	Allow $p \propto T$ Reference to $p = nRT/V$	(1)



Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to the following points: - fewer protons (in nitrogen) (1) - result in a weaker nuclear attraction because shielding is the same/electrons are in the same (sub)shell (in oxygen)/same number of electron shells (1)	Reference to molecule scores (0) Accept reverse arguments in terms of oxygen Allow weaker (effective) nuclear charge Allow smaller atomic number Do not award if incorrect numbers of protons stated or if ions referred to Do not award 'charge density' Ignore references to electron repulsion and electronegativity	(2)

(Total for Question 4 = 6 marks)



Question number	Answer	Mark
3(a)	The only correct answer is D (urea, $\text{CO}(\text{NH}_2)_2$) <i>A is incorrect because ethanamide has M_r of 59.037</i> <i>B is incorrect because ethanoic acid has M_r of 60.021</i> <i>C is incorrect because trimethylamine has M_r of 59.0733</i>	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)	- calculation of mol of gas (1) - calculation of molar mass (1)	<u>Example of calculation</u> mol of gas = $\frac{5.40}{24.0} = 0.225$ (mol) molar mass = $\frac{9.90}{0.225} = 44.0 / 44$ (g mol^{-1}) TE on mol gas Ignore SF except 1 SF Ignore units Correct answer with no working scores (2)	(2)



Question Number	Answer	Additional Guidance	Mark
3(c)	- conversion of pressure, temperature and volume - rearrangement of ideal gas equation - calculation of n - calculation of molar mass and answer to 2 / 3 SF	<u>Example of calculation</u> pressure = $100.6 \times 10^3 = 1.006 \times 10^5$ Pa and temperature = $273 + 95.0 = 368$ K and volume = $60.0 \times 10^{-6} = 6.00 \times 10^{-5} \text{ m}^3$ $n = \frac{pV}{RT}$ Allow values correctly substituted into $pV = nRT$ $n = \frac{1.006 \times 10^5 \times 6.00 \times 10^{-5}}{8.31 \times 368} = 1.9738 \times 10^{-3}$ TE on p, V and T Molar mass = $\frac{0.170}{1.9738 \times 10^{-3}} = (86.129) = 86 / 86.1 (\text{g mol}^{-1})$ TE on n Ignore units. If their final answer is less than 1 do not award the final mark	(4)

(Total for Question 3 = 7 marks)



Question Number	Answer	Additional Guidance	Mark									
4(a)	- calculation of mol of CO₂ - calculation of masses of C and H - calculation of mol and ratio of C : H - empirical formula	(1) <u>Example of calculation</u> mol CO₂ = $\frac{7.59}{44} = 1.725 \times 10^{-1} / 0.1725$ (mol) (1) mass C = $0.1725 \times 12 = 2.07$ (g) or $\frac{12}{44} \times 7.59 = 2.07$ (g) subsumes M1 as well and mass H = $2.50 - 2.07 = 0.43$ (g) <table><tr><td></td><td>C</td><td>H</td></tr><tr><td>mol</td><td>$\frac{2.07}{12}$ = 0.1725</td><td>$\frac{0.43}{1}$ = 0.43</td></tr><tr><td>ratio</td><td>$\frac{0.1725}{0.1725}$ = 1</td><td>$\frac{0.43}{0.1725}$ = 2.4928</td></tr></table> (1) C₂H₅ Correct answer with no working scores 1 Correct answer with some working scores 4		C	H	mol	$\frac{2.07}{12}$ = 0.1725	$\frac{0.43}{1}$ = 0.43	ratio	$\frac{0.1725}{0.1725}$ = 1	$\frac{0.43}{0.1725}$ = 2.4928	(4)
	C	H										
mol	$\frac{2.07}{12}$ = 0.1725	$\frac{0.43}{1}$ = 0.43										
ratio	$\frac{0.1725}{0.1725}$ = 1	$\frac{0.43}{0.1725}$ = 2.4928										

Question number	Answer	Mark
4(b)(i)	The only correct answer is A (accepts a pair of electrons) <i>B is incorrect because electrophiles involve a pair of electrons, not an unpaired electron</i> <i>C is incorrect because nucleophiles donate a pair of electrons</i> <i>D is incorrect because nucleophiles donate a pair of electrons, not an unpaired electron</i>	(1)



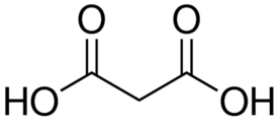
Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An explanation that makes reference to the following points: - benzene (is resistant to bromination because it) has delocalisation of electrons / delocalised electrons (in π bonds) (1) - benzene is (kinetically) stable or the activation energy for the reaction is high (1) - ethene (reacts readily because it) has localised electron density (in one π bond) / does not have delocalised electrons or increased / high electron density (of the double / π bond compared to benzene) (1) - which makes it more susceptible to / easier to undergo electrophilic attack (than benzene) (1)	Allow more energy is required to break up the structure of benzene Allow a (Friedel-Crafts) catalyst / halogen carrier / AlCl_3, FeBr_3 is needed Allow ethene has a $\text{C}=\text{C}$ / (carbon – carbon) double bond Allow benzene is less susceptible to electrophilic attack (than ethene) Allow the π / double bond in ethene is weaker (than in benzene) Allow ethene is a better nucleophile (than benzene) Allow the Br_2 / $\text{Br}-\text{Br}$ is more easily polarised (by ethene) Do not award electrophilic attack by Br^+ If no other mark scored allow (1) for ‘benzene undergoes substitution and ethene undergoes addition’	(4)

(Total for Question 4 = 9 marks)



Question Number	Answer	Additional Guidance	Mark
8(a)	- calculation of mass of C and H in CO₂ and H₂O (1) - calculation of mass of O in acid (1) - calculation of moles of C, H and O (1) - deduction of empirical formula (1)	<u>Example of calculation</u> 0.68455 g C and 0.076667 g H 1.21878 g of O Amount of C = $0.68455/12 = 0.05705$ mol Amount of H = $0.076667/1 = 0.076667$ mol Amount of O = $1.21878/16 = 0.076174$ mol 1 : 1.34 : 1.34 = 3:4:4 C₃H₄O₄ Allow TE throughout Ignore SF Ignore minor rounding errors e.g. 0.684 g of C NOTE do not award $(2.51 + 0.69) - 1.98 = 1.22$ g for M2 as this is molecular oxygen from combustion NOT oxygen from compound Y	(4)



Question Number	Answer	Additional Guidance	Mark
8(b)	- calculation of amount of sodium hydroxide (1) - calculation of amount of Y in 25.0 cm³ (1) - calculation of amount of Y in 250 cm³ (1) - calculation of molar mass of Y (1) - deduction of structure of Y (1)	<u>Example of calculation</u> $26.10/1000 \times 0.320 = 8.352 \times 10^{-3} \text{ (mol)}$ $8.352 \times 10^{-3} / 2 = 4.176 \times 10^{-3} \text{ (mol)}$ $4.176 \times 10^{-3} \times (250/25) = 4.176 \times 10^{-2} \text{ (mol)}$ $4.34 / 4.176 \times 10^{-2} = 103.9 / 104 \text{ (g mol}^{-1}\text{)}$  Allow structural / displayed / skeletal or any combination Allow TE throughout M1-M4 Penalise 1 SF in M1	(5)

Question Number	Answer	Mark
8(c)	The only correct answer is A (LiAlH₄ and ether) <i>B is incorrect as acidified KMnO₄ is an oxidising agent</i> <i>C is incorrect as Sn/HCl is too mild a reducing agent</i> <i>D is incorrect as acidified Na₂Cr₂O₇ is an oxidising agent</i>	(1)

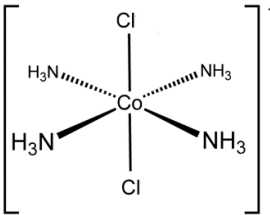
(Total Question 8 = 10 marks)



Question Number	Answer	Additional Guidance	Mark															
5(a)(i)	An answer that makes reference to the following points: - calculate moles of each element - show ratio by division by smallest number and show RFM of $\text{CoN}_4\text{H}_{12}\text{Cl}_3$ is 233.4	<table><tr><td></td><td>Co</td><td>N</td><td>H</td><td>Cl</td></tr><tr><td>mol</td><td>$1.26 \div 58.9$ $= 0.0214$</td><td>$1.20 \div 14.0$ $= 0.0857$</td><td>$0.257 \div 1.0$ $= 0.257$</td><td>$2.28 \div 35.5$ $= 0.0642$</td></tr><tr><td>ratio</td><td>$0.0214 / 0.0214$ $= 1$</td><td>$0.0857 / 0.0214$ $= 4$</td><td>$0.257 / 0.0214$ $= 12$</td><td>$0.0642 / 0.0214$ $= 3$</td></tr></table> $(58.9 + (4 \times 14) + 12 + (3 \times 35.5)) = 233.4$ (so molecular formula = $\text{CoN}_4\text{H}_{12}\text{Cl}_3$) M1 % of each element by mass in sample of 4.997 g M2 % of each element by comparing ΣA_r to M_r		Co	N	H	Cl	mol	$1.26 \div 58.9$ $= 0.0214$	$1.20 \div 14.0$ $= 0.0857$	$0.257 \div 1.0$ $= 0.257$	$2.28 \div 35.5$ $= 0.0642$	ratio	$0.0214 / 0.0214$ $= 1$	$0.0857 / 0.0214$ $= 4$	$0.257 / 0.0214$ $= 12$	$0.0642 / 0.0214$ $= 3$	(2)
	Co	N	H	Cl														
mol	$1.26 \div 58.9$ $= 0.0214$	$1.20 \div 14.0$ $= 0.0857$	$0.257 \div 1.0$ $= 0.257$	$2.28 \div 35.5$ $= 0.0642$														
ratio	$0.0214 / 0.0214$ $= 1$	$0.0857 / 0.0214$ $= 4$	$0.257 / 0.0214$ $= 12$	$0.0642 / 0.0214$ $= 3$														

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	EITHER - calculation of moles of AgCl / Cl⁻ (1) - calculation of moles of R (1) and show ratio is 1:1 (so one mole of R releases 1 mol of chloride ions) OR - calculation of moles of R (1) - calculation of moles of AgCl / Cl⁻ (1) and show ratio is 1:1 (so one mole of R releases 1 mol of chloride ions)	<u>Example of calculation</u> moles of AgCl = $0.614 \div 143.4 = 4.2817 \times 10^{-3}$ mol moles of R = $1.00 \div 233.4 = 4.2845 \times 10^{-3}$ mol 4.2845×10^{-3} mol : 4.2817×10^{-3} mol $\approx$ 1:1, (so 1 mol of R releases 1 mol of chloride ions) Do not award 3Cl⁻ ions moles of R = $1.00 \div 233.4 = 4.2845 \times 10^{-3}$ mol moles of AgCl = $0.614 \div 143.4 = 4.2817 \times 10^{-3}$ mol 4.2845×10^{-3} mol : 4.2817×10^{-3} mol $\approx$ 1:1, (so 1 mol of R releases 1 mol of chloride ions) Do not award 3Cl⁻ ions Ignore SF except 1 SF	(2)



Question Number	Answer	Additional Guidance	Mark
5(a)(iii)	An answer that makes reference to the following points: - octahedral shape (around cobalt) using wedges (1) - correct number and type of ligand (1) - correct overall charge (1)	 Allow dashed line for dashed wedges Allow '+' on cobalt Allow correct calculation of charge from incorrect ligands Ignore position of Cl ligands relative to NH₃ ligands Ignore connectivity Ignore omission of square brackets Ignore additional chloride ion (to form R) Arrows if drawn must be pointing towards the cobalt	(3)

Question Number	Answer	Additional Guidance	Mark
5(b)(i)	An answer that makes reference to the following points: - forward and backward reactions proceed at the same rate (1) - concentration of reactants and products remain constant / remain the same (1)	Do not award rates of forward and backward reactions are constant Accept resulting in no observable change in the system	(2)



Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	An explanation that makes reference to the following points: • (The most stable is) $[\text{Co}(\text{EDTA})]^{2-}(\text{aq})$ as it has the larger (log) K_c / eqm lies furthest to RHS (1) • 2 moles (of ions) forms 7 moles (of product in EDTA equation) (1) • (greater) increase in entropy (change of the system) / ΔS_{sys} is positive (1)	Ignore calculated K_c values Allow more moles of product than reactant Allow species Do not award 'molecules' Do not award increase in entropy if clear that it is referring to the EDTA (complex) and not the reaction	(3)

(Total for Question 5 = 12 marks)

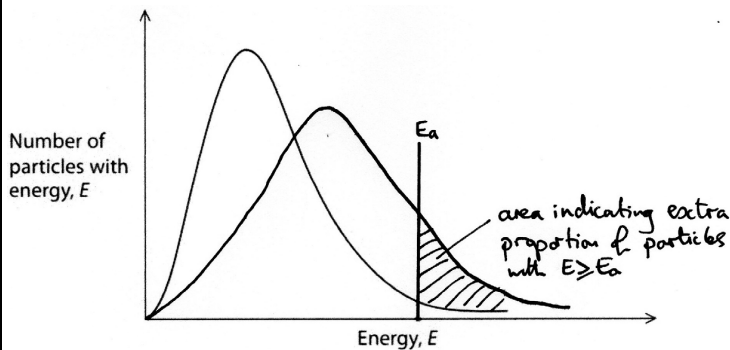


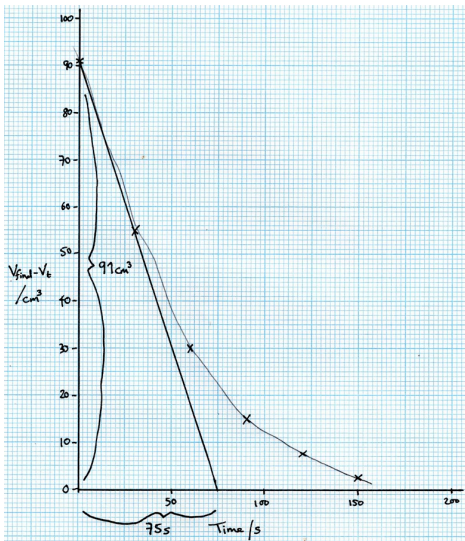
Question Number	Answer	Additional Guidance	Mark
5(a)	- calculation of moles of calcium carbonate (1) - calculation of moles of hydrochloric acid (1) - calculation of dm^3 volume of hydrochloric acid (1) - conversion to cm^3 volume and 2/3 SF (1)	<u>Example of calculation</u> $n = (0.355 \div 100.1) = 0.0035465 / 3.5465 \times 10^{-3} \text{ (mol)}$ allow use of 100 $n = (0.0035465 \times 2)$ $= 0.0070929 / 7.0929 \times 10^{-3} \text{ (mol)}$ $V = (0.0070929 \div 0.100)$ $= 0.070929 / 7.0929 \times 10^{-2} \text{ (dm}^3\text{)}$ $V = (0.070929 \times 1000)$ $= (70.929) = 71 / 70.9 \text{ (cm}^3\text{)}$ Do not award 71.0 if 100.1 has been used as M_r Ignore SF for M1 to M3 except 1 SF TE at each stage Correct answer with some (correct) working scores (4)	(4)

Question Number	Answer	Additional Guidance	Mark
5(b)	An answer that makes reference to the following point: powdered carbonate has greater surface area	Allow SA for surface area Allow description of greater surface area	(1)



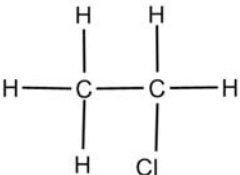
Question Number	Answer	Additional Guidance	Mark
5(c)(i)	- conversion of pressure and temperature - rearrangement of ideal gas equation - calculation of volume - Correct units for volume and a statement that this is not measurable as volume exceeds volume of the gas syringe	(1) <u>Example of calculation</u> pressure = 1×10^5 Pa and temperature = 347.0 K (1) $V = \frac{nRT}{P}$ M2 may be subsumed in M3 (1) $V = \frac{(4.19 \times 10^{-3} \times 8.31 \times 347.0)}{1 \times 10^5}$ $= 1.2082 \times 10^{-4} \text{ (m}^3\text{)} / 121 \text{ (cm}^3\text{)}$ Ignore units for M3, even if incorrect Ignore SF except 1 SF TE for M3 (1) If no units given in M3, assume m^3 from the ideal gas equation TE on incorrect volume ($< 5 \text{ cm}^3$) for M3, with correct units and reasonable suggestion as to why the apparatus would not give a measurable result	(4)

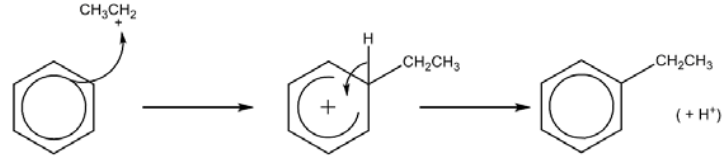
Question Number	Answer	Additional Guidance	Mark
5(c)(ii)	An answer that makes reference to the following points: - line added to the right of the existing line and with a lower peak - activation energy line added to the right of both line peaks - shaded area(s) of particles $\geq E_a$, plus annotation or greater proportion of particles exceed the activation energy	Do not award the line crossing the other line twice Do not award the curve crossing the x-axis Do not award a line which goes up on the right or that plateaus high above the x axis, <u>Example of graph</u> Note – Example below scores all three marks with no further explanation needed  (1) (1) (1) Allow more molecules/particles have energy greater than the activation energy Do not award M3 if there is any reference to the activation energy decreasing/increasing Ignore ‘more particles have the required activation energy’ Ignore reference to just higher frequency of collisions	(3)

Question Number	Answer	Additional Guidance	Mark
5(d)	- tangent showing initial rate drawn on graph or relevant working on graph (1) - calculation of rate with units (1)	<u>Example of graph and calculation</u>  rate = $(91 \text{ cm}^3 \div 75 \text{ s})$ $= 1.2133 / 1.213 / 1.21 / 1.2 \text{ cm}^3 \text{ s}^{-1}$ Allow range of $1.1 - 1.3 \text{ cm}^3 \text{ s}^{-1}$ Ignore SF except 1SF Ignore sign If no other marks awarded, allow TE from a tangent/gradient calculated at a point from any part of the curve	(2)

(Total for Question 5 = 14 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)		Do not award skeletal or structural formulae	(1)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	M1 equation to show formation of electrophile (1) M2 curly arrow from anywhere on the central ring to positive carbon (1) M3 structure of intermediate (1) M4 curly arrow from C-H bond to reform the ring (1) M5 equation showing regeneration of catalyst (1)	<u>Example of mechanism</u> Penalise incorrect halogenoalkane in (a)(i) only $\text{CH}_3\text{CH}_2\text{Cl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{CH}_2^+ + \text{AlCl}_4^-$ Ignore any curly arrows given in the equation Allow curly arrow from anywhere within the hexagon Do not award if curly arrow to CH_3 carbon in CH_3CH_2^+ Do not award if curly arrow to C_2H_5^+ Horseshoe facing the tetrahedral carbon and covering at least three carbon atoms Some part of the positive charge in the horseshoe Do not award dotted lines unless clearly part of a 3D structure $\text{AlCl}_4^- + \text{H}^+ \rightarrow \text{AlCl}_3 + \text{HCl}$ Ignore regeneration step if part of the mechanism Mechanism  Allow TE from (a)(i)	(5)

Question Number	Answer	Additional Guidance	Mark
5(a)(iii)	An explanation that makes reference to the following points: Phenol is likely to be more reactive because • M1 lone pair on oxygen (atom of -OH group) delocalises / is incorporated into the (benzene) ring / donated to the ring (1) • M2 which increases the electron density (of the ring) (1) • M3 making the ring / phenol more susceptible to electrophilic attack (1)	Do not award M2 if mention of "charge density" / "electronegativity" Ignore references to "the ring becomes more negative" Award "making the ring more nucleophilic" / "making the ring more susceptible to attack by a positive ion" Ignore references to "activation of the ring"	(3)



Question Number	Answer	Additional Guidance	Mark
5(b)	• M1 conversion of pressure and temperature (1) • M2 conversion of volume units (1) • M3 rearrangement of gas equation and calculation of n (1) • M4 calculation of the molar mass with the final answer given to 2 or 3 SF (1)	<u>Example of calculation</u> 118 000 (Nm⁻²) and 438 (K) 70.5 x 10⁻⁶ / 7.05 x 10⁻⁵ (m³) $n = \frac{pV}{RT}$ $n = \frac{(118000 \times 70.5 \times 10^{-6})}{(8.31 \times 438)}$ $n = 2.2855777 \times 10^{-3} \text{ (mol)}$ $\frac{0.271}{2.2855777 \times 10^{-3}}$ $= 118.5696$ $= 119 / 120 \text{ (g mol}^{-1}\text{)}$ If use $M_r = \frac{mRT}{pV}$ (since $n = \frac{m}{M_r}$) can score both M3 and M4 $M_r = \frac{0.271 \times 8.31 \times 438}{118\,000 \times 70.5 \times 10^{-6}}$ $M_r = 118.5695$ $M_r = 119 / 120 \text{ (g mol}^{-1}\text{)}$ Award TE at each stage Ignore units even incorrect	(4)



Question Number	Answer	Additional Guidance	Mark
5(c)	An explanation that makes reference to the following points: EITHER - retention time depends on the polarity or attraction / affinity / solubility / of the component for the stationary phase (1) - The greater attraction / affinity / solubility / of the component for the stationary phase the greater the retention time (1) OR - retention time depends on the boiling temperature of the compound (1) - higher boiling temperature compounds spend less time in the gas phase / mobile phase so have longer retention time (1)	Allow 'solid phase' or 'liquid phase' for 'stationary phase' Allow 'retention time depends interaction with stationary phase' Ignore attractions to the mobile / gas phase Ignore comments related to mass of compounds	(2)

(Total Question 5 = 15 marks)



Question Number	Answer	Mark
2(a)	The only correct answer is A ($\text{CH}_3\text{COOH} > \text{CH}_2\text{ClCOOH} > \text{HCl}$) <i>B is incorrect because HCl is the only strong acid, so would have the lowest pH</i> <i>C is incorrect because CH_2ClCOOH is stronger than CH_3COOH as the Cl atom stabilises the anion</i> <i>D is incorrect because the stronger the acid the lower the pH, hence these are in reverse order</i>	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)	- calculation of $[\text{H}^+]$ (1) - use of K_a expression to calculate K_a (1) - calculation of $\text{p}K_a$ (1)	Example of calculation $[\text{H}^+] = 10^{-2.20} = 6.3096 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ $K_a = (6.3096 \times 10^{-3})^2 / 0.240$ $= 1.6588 \times 10^{-4}$ $\text{p}K_a = -\log [1.6588 \times 10^{-4}] = 3.7802$ ignore SF except 1SF ignore units allow TE throughout correct answer with no working scores 3	(3)



Question Number	Answer	Mark
2(c)	The only correct answer is B (NaOH(aq) and excess CH₃COOH(aq)) <i>A is incorrect because the solutions would not form a buffer</i> <i>C is incorrect because the solutions would not form a buffer</i> <i>D is incorrect because the solutions would not form a buffer</i>	(1)

Question Number	Answer	Mark
2(d)	The only correct answer is D (none of these three indicators) <i>A is incorrect because both acid and base are weak so pH range at equivalence is too narrow for bromothymol blue to change colour</i> <i>B is incorrect because both acid and base are weak so pH range at equivalence is too narrow for methyl orange to change colour</i> <i>C is incorrect because both acid and base are weak so pH range at equivalence is too narrow for phenolphthalein to change colour</i>	(1)

(Total Question 2 = 6 marks)



Question Number	Answer	Mark
3(a)(i)	The only correct answer is D <i>A is not correct because the measurement uncertainty is doubled as there are two burette readings</i> <i>B is not correct because this gives the largest measurement uncertainty</i> <i>C is not correct because the measurement uncertainty is doubled as the pipette is used twice</i>	(1)

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	- calculation of Q (1) - calculation of enthalpy change (1) - answer to nearest whole number and with negative sign (1)	<u>Example of calculation</u> $Q = (100 \times 4.18 \times 6.5) = 2717 \text{ (J)} / 2.717 \text{ kJ}$ $\Delta H = 2.717 \div 0.05 = (-)54.340$ $= -54 \text{ (kJ mol}^{-1}\text{)}$ Allow TE at each stage Correct answer with no working scores (3)	(3)

Question Number	Answer	Mark
3(b)(i)	The only correct answer is B <i>A is not correct because there is no extrapolation to the largest temperature increase carried out</i> <i>C is not correct because the extrapolation is at the wrong time</i> <i>D is not correct because the extrapolation extends beyond the time of addition of alkali</i>	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An explanation that makes reference to - ethanoic acid is a weak(er) acid / only partially ionised/dissociated (1) (some) energy is used to fully/completely ionise the ethanoic acid (1)	Allow hydrochloric acid is a strong(er) acid/fully ionised Do not award 'more NaOH will react so more energy given off'	(2)

(Total Question 3 = 7 marks)



Question Number	Answer	Additional Guidance	Mark
9(a)	An answer that makes reference to the following points - structure of A as 2-chloropropane (1) - structure of B as propan-2-ol (1) - structure of C as propanone (1) - structure of D as 2-propylmagnesium chloride (1) - structure of E as 2-methylpropanoic acid (1)	Allow displayed formulae, any combination of structural and displayed formulae or skeletal formulae Ignore names even if incorrect $\text{CH}_3\text{CHClCH}_3$ $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ Allow structure of propan-1-ol if A is 1-chloropropane CH_3COCH_3 Allow structure of propanal if A is 1-chloropropane Do not allow propanoic acid as the formula is incorrect. $\text{CH}_3\text{CH}(\text{MgCl})\text{CH}_3$ Allow $\text{CH}_3\text{CH}(\text{ClMg})\text{CH}_3$ $\text{CH}_3\text{CH}(\text{CH}_3)\text{COOH}$ TE throughout	(5)



Question Number	Answer	Additional Guidance	Mark
9(b)	- calculation of mol of NaOH (1) - calculation of mol HCl in 100 cm³ (1) - calculation of mol HCl at start (1) - calculation of mol NH₃ reacted with HCl (1) - calculation of percentage of N in compound (1)	<u>Example of calculation</u> mol of NaOH = $\frac{15.5 \times 0.100}{1000} = 1.55 \times 10^{-3} / 0.00155$ (mol) mol HCl = $4 \times 1.55 \times 10^{-3} = 6.2 \times 10^{-3} / 0.0062$ (mol) mol HCl at start = $\frac{100 \times 0.225}{1000} = 2.25 \times 10^{-2} / 0.0225$ (mol) mol NH₃ = $0.0225 - 0.0062 = 0.0163 / 1.63 \times 10^{-2}$ (mol) mass N = $0.0163 \times 14 = 0.2282$ (g) and % N = $\frac{0.2282 \times 100}{1.19} = 19.176$ (%) Allow TE at each stage but M5 must be <100% Correct answer scores 5 Ignore SF except 1 SF	(5)

(Total for Question 9 = 10 marks)



Question Number	Answer	Additional Guidance	Mark																				
9(a)	titre 3 correct and initial burette reading 4 correct	<u>Example of table</u> <table><tr><th>Titration number</th><th>1</th><th>2</th><th>3</th><th>4</th></tr><tr><td>Final burette reading / cm³</td><td>(15.90)</td><td>(24.00)</td><td>(15.30)</td><td>(25.00)</td></tr><tr><td>Initial burette reading / cm³</td><td>(0.00)</td><td>(8.45)</td><td>(0.05)</td><td>9.35</td></tr><tr><td>Titre / cm³</td><td>(15.90)</td><td>(15.55)</td><td>15.25</td><td>(15.65)</td></tr></table>	Titration number	1	2	3	4	Final burette reading / cm ³	(15.90)	(24.00)	(15.30)	(25.00)	Initial burette reading / cm ³	(0.00)	(8.45)	(0.05)	9.35	Titre / cm ³	(15.90)	(15.55)	15.25	(15.65)	(1)
Titration number	1	2	3	4																			
Final burette reading / cm ³	(15.90)	(24.00)	(15.30)	(25.00)																			
Initial burette reading / cm ³	(0.00)	(8.45)	(0.05)	9.35																			
Titre / cm ³	(15.90)	(15.55)	15.25	(15.65)																			

Question Number	Answer	Additional Guidance	Mark
9(b)	An answer that makes reference to the following point: the mean / average of the concordant titres	Allow titres 2 and 4 / 15.55 and 15.65 to identify the relevant titres Do not award all four titrations added together and divided by four	(1)



Question Number	Answer	Additional Guidance	Mark
9(c)	An answer that makes reference to the following points: (from) colourless (1) (to) (pale) pink (1)	Do not award pink – purple / dark pink / purple / red Allow one mark for correct colours reversed	(2)

Question Number	Answer	Additional Guidance	Mark
9(d)	- moles of $\text{KMnO}_4(\text{aq}) / \text{MnO}_4^-(\text{aq})$ used in titration (1) - moles H_2O_2 in 25.0 cm^3 of the diluted sanitiser (1) - moles H_2O_2 in the 250 cm^3 of solution = moles in 10.0 cm^3 of hand sanitiser (1) - mass H_2O_2 in 10 cm^3 hand sanitiser (1) % by mass of H_2O_2 in hand sanitiser and this is within the (WHO) guidelines (1)	<u>Example of calculation</u> $= 0.0200 \times \frac{15.60}{1000} = 3.12 \times 10^{-4} / 0.000312 \text{ (mol)}$ $= (3.12 \times 10^{-4} / 2) \times 5 = 7.80 \times 10^{-4} / 0.000780 \text{ (mol)}$ $= 7.80 \times 10^{-4} \times 10 = 7.80 \times 10^{-3} / 0.00780 \text{ (mol)}$ M3 could be carried out before M2 $= 34 \times 7.80 \times 10^{-3} = 0.2652 \text{ (g)}$ $= \frac{0.2652}{8.2} \times 100 = 3.23 \text{ (%)}$ Ignore SF except 1 SF Allow TE throughout unless greater than 100% Allow alternative method for M4 and M5 using concentrations of H_2O_2 in mol dm^{-3}	(5)



Question Number	Answer	Additional Guidance	Mark
9(e)	• pipette uncertainty (1) • burette uncertainty (1)	<u>Example of calculation</u> $= \frac{0.04}{25} \times 100 = (\pm) 0.16\%$ $= \frac{0.05}{15.55} \times 2 \times 100 = (\pm) 0.643 / 0.64\%$ Ignore absence of labels 'pipette' and 'burette' If labels given but wrong way round allow 1 mark for 2 correct numerical values Allow any SF except 1 SF Accept correct answers without working Penalise 1 SF once only	(2)

(Total for Question 9 = 11 marks)



Question Number	Answer	Mark
8(a)	The only correct answer is C <i>A is not correct because this is for a 100-fold increase in concentration</i> <i>B is not correct because this is for no change in concentration</i> <i>D is not correct because this is for a 10000-fold decrease in concentration</i>	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)	- calculation of $[H^+]$ (1) - expression relating K_a, $[H^+]$ and $[CH_2OHCOOH]$ (1) - calculation of $[CH_2OHCOOH]$ (1)	<u>Example of calculation</u> $[H^+] = 10^{-pH} = 0.01 / 1 \times 10^{-2} / 10^{-2} \text{ (mol dm}^{-3}\text{)}$ $K_a = \frac{[H^+]^2}{[CH_2OHCOOH]}$ or $[CH_2OHCOOH] = \frac{[H^+]^2}{K_a}$ Allow [HA] in M2 and M3 $[CH_2OHCOOH] = \frac{0.01^2}{1.5 \times 10^{-4}}$ $= 0.667 / 0.67 \text{ (mol dm}^{-3}\text{)}$ Ignore SF except 1 SF Ignore units Correct answer with no working scores (3)	(3)

Question Number	Answer	Additional Guidance	Mark
8(c)(i)	- named indicator (1) - matching colour change (1) - pH range (of indicator) / quoted range lies (completely) in the vertical region (on the titration curve) or - indicator will change colour in the vertical / straight / steep region of the graph or - pH range of indicator and pH range of vertical region of the graph stated, as long as they overlap (1)	<u>Examples of indicators and colour changes</u> phenol red – red to orange / yellow phenolphthalein ((in ethanol)) – red / pink to colourless (do not allow purple or clear) bromothymol blue – blue to yellow M2 is conditional on a correct indicator in M1 Do not allow unsuitable indicators e.g. litmus Stand alone mark Allow $pK_{in} (\pm 1)$ is in the vertical jump or pK_{in} is nearest to the pH at the end / equivalence point or indicator will change colour at the end / equivalence point or (because it is a) titration of a weak acid with a strong base	(3)

Question Number	Answer	Mark
8(c)(ii)	The only correct answer is C <i>A is not correct because used the volumes the wrong way round</i> <i>B is not correct because not used the volume of glycolic acid from the graph</i> <i>D is not correct because used a 1:2 mole ratio</i>	(1)

Question Number	Answer	Mark
8(c)(iii)	The only correct answer is C <i>A is not correct because this is the pH of glycolic acid</i> <i>B is not correct because this is the pH at the end of the vertical jump in the curve</i> <i>D is not correct because this is the pH at the start of the vertical jump</i>	(1)

Question Number	Answer	Additional Guidance	Mark
8(d)(i)	An explanation that makes reference to the following points: - the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH₂OH) withdraws / attracts electrons (1) - stabilises the anion / CH₂OHCOO⁻ ion or weakens O-H bond in acid so hydrogen ion / H⁺ lost more easily (1)	Allow reference to intramolecular hydrogen bonding Allow hydrogen ion / H⁺ more easily dissociates	(2)

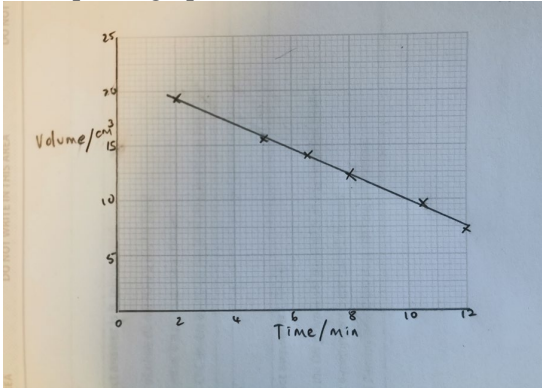
Question Number	Answer	Additional Guidance	Mark
8(d)(ii)	$(\text{CH}_2\text{OHCOOH} + \text{CH}_3\text{COOH} \rightarrow)$ $\text{CH}_2\text{OHCOO}^- + \text{CH}_3\text{COOH}_2^+$	Both correct for the mark Allow formulae in either order Allow formulae in brackets with charge outside Allow displayed formulae Do not allow $\text{CH}_3\text{C}(\text{OH})_2^+$	(1)

(Total for Question 8 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
10(a)(i)	An explanation that makes reference to the following points: - to stop / freeze / quench the reaction (1) - by neutralising the (remaining sulfuric) acid / H^+ (1)	Allow 'to allow time for the titration to be carried out' Ignore just 'slows down the reaction' Allow by reacting with the acid / removing the acid Allow catalyst for acid Do not award if incorrect acid specified	(2)

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	ionic equation	<u>Examples of equations</u> $NaHCO_3 + H^+ \rightarrow CO_2 + H_2O + Na^+$ Or $NaHCO_3 + H_3O^+ \rightarrow CO_2 + 2H_2O + Na^+$ Allow $HCO_3^- + H^+ \rightarrow CO_2 + H_2O$ $HCO_3^- + H^+ \rightarrow H_2CO_3$ Allow multiples Allow balanced equations with H_3O^+ Allow Na^+ and SO_4^{2-} in equations, provided they are crossed through Ignore state symbols, even if incorrect Do not award $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$	(1)

Question Number	Answer	Additional Guidance	Mark
10(b)(i)	- y axis labelled with volume and cm^3 and x axis labelled with time and min and suitable scale (1) - all points plotted correctly and line of best fit (1)	<u>Example of graph</u>  Do not award time in seconds Suitable scale so that points cover at least half the available space along the x axis and at least 2 large squares on y axis (as shown) $\pm \frac{1}{2}$ a small square Allow M2 as TE if axes wrong way around Ignore extrapolations	(2)

Question Number	Answer	Additional Guidance	Mark
10(b)(ii)	An explanation that makes reference to the following points: $[I_2]$ is proportional to the volume (of sodium thiosulfate) (1) - gradient does not change / is constant / the graph shows a straight line / is linear (as $[I_2]$ decreases) (1) - which means the rate doesn't change / increase or decrease (as $[I_2]$ increases or decreases) (1)	Ignore references to half-life Allow description of proportional Allow decreases at a constant rate Ignore volume (of sodium thiosulfate) / $[I_2]$ is proportional to time Allow $[I_2]$ does not affect the rate (of reaction) / rate is independent of $[I_2]$	(3)

Question Number	Answer	Additional Guidance	Mark
10(c)(i)	An answer that makes reference to the following points: - Step 1 is the rate determining step (1) - as it involves (1 mol of) both propanone and hydrogen ions (which matches the rate equation) (1)	Stand alone Allow RDS / slow step Conditional on M1 Allow it does not involve I_2 (which is zero order) Allow it involves both species in the rate equation Allow I_2 is not involved in the RDS so RDS must be before Step 2	(2)



Question Number	Answer	Additional Guidance	Mark
10(c)(ii)	An explanation that makes reference to the following points: (The statement is not valid because) - one hydrogen ion is regenerated / reformed (so is acting as a catalyst) (1) - the other hydrogen ion is lost from the propanone (when replaced by iodine) / is a (by-)product of the reaction / is used to form HI (1)	Ignore reference to specific steps. Do not award M1 if candidate states that it is valid Ignore it is an autocatalyst	(2)

(Total for Question 10 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
9(a)(i)	An answer that makes reference to one of the following points: - the colour of the pineapple juice masks the colour change or - methyl orange only works with a strong acid or - methyl orange does not change colour in the vertical section of the titration curve	Allow methyl orange is a similar colour to pineapple juice Accept methyl orange cannot be used with a weak acid (and strong alkali) Allow the pH range / 3.2-4.4 / pK_{in} of methyl orange is below the equivalence point / too low Allow the colour change would occur before the equivalence point / is not over the equivalence point Allow the pH at the equivalence point is not in the pH range of methyl orange Allow end point for equivalence point Ignore just 'no colour change observed' Ignore just 'end point is not accurate'	(1)

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	An explanation that makes reference to the following points: - the titre value would be greater (than expected) (1) - as the titre value includes the volume of the air bubble (as well as sodium hydroxide solution) (1)	M2 conditional on M1 scored Allow some alkali / solution is used to fill the air bubble / jet Allow there is less sodium hydroxide in the burette than expected	(2)



Question Number	Answer	Additional Guidance	Mark
9(b)(i)	An explanation that makes reference to the following points: (at the end point) all ascorbic acid is used up so the iodine is no longer reduced (to iodide ions) or ascorbic acid reacts with the iodine until all the (ascorbic) acid is used up (1) - the (slight excess) iodine reacts / forms complex with the starch (1) (changing from yellow) to a blue/black colour (1)	Stand alone Allow starch in the presence of iodine Do not award starch and iodide ions Stand alone Allow just black or just (dark) blue Ignore initial colour of solution Do not award blue/black to colourless	(3)



Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	- calculation of amount of IO_3^- (aq) (1) - calculation of amount of iodine / ascorbic acid in 5.00 cm^3 sample (1) - calculation of amount of ascorbic acid in 150.0 cm^3 sample (1) - calculation of amount of citric acid in 150.0 cm^3 sample (1) - calculation of mass of citric acid in 150.0 cm^3 sample (1)	<u>Example of calculation</u> $= (9.50/1000) \times 0.00100 = 9.50 \times 10^{-6} \text{ (mol)}$ $= 9.50 \times 10^{-6} \times 3 = 2.85 \times 10^{-5} \text{ (mol)}$ TE on M1 $= 2.85 \times 10^{-5} \times 30 = 8.55 \times 10^{-4} \text{ (mol)}$ TE on M2 $= 8.00 \times 10^{-3} - 8.55 \times 10^{-4} = 7.145 \times 10^{-3} \text{ (mol)}$ TE on M3 $= 7.145 \times 10^{-3} \times 192 = 1.37184 \text{ g} = 1.37 \text{ (g)}$ TE on M4 Ignore SF except 1 SF Correct answer with some or no working scores (5)	(5)



Question Number	Answer	Additional Guidance	Mark
9(c)	An explanation that makes reference to the following points: - compound E and as it has (two) COOH / (carboxylic) acid group(s) (1) - these / this will (also) react with the NaOH / in the titration (in Experiment 1) (1) (the titre will be greater in Experiment 1 so suggests a greater total amount of acid) so the final mass of citric acid calculated will be greater (than the true amount) or the total amount of acid (calculated from the titration) includes citric acid and E so the actual mass of citric acid is less (than calculated in (b)(ii) (1)	Allow Compound E is a (di)carboxylic acid Ignore reference to OH group Do not award carbonyl group(s) Do not award if OH group reacts with NaOH Conditional on compound E selected	(3)

(Total for Question 9 = 14 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
10(a)	An answer that makes reference to the following points: (dissolve) in deionised water (in a beaker) (1) and transfer to a volumetric flask (wash the beaker and) transfer the washings (1) - make up to the mark and invert / mix (thoroughly) (1)	Steps have to be in a logical order. Allow distilled for deionised Allow direct transfer of the solid to the volumetric flask Ignore use of pestle and mortar Comment allow this mark as long as deionised /distilled water is seen in the response Allow any indication of mixing eg shaking / stirring / etc	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
10(b)(i)	An answer that makes reference to the following point: $\text{IO}_3^- + 5\text{I}^- + 6\text{H}^+ \rightarrow + 3\text{I}_2 + 3\text{H}_2\text{O}$		(1)



Question Number	Acceptable Answer	Additional Guidance	Mark
10(b)(ii)	- moles potassium iodate (1) - moles iodine generated (1)	<u>Example of calculation</u> $0.01 \times 0.025 = 2.5 \times 10^{-4}$ $3 \times 2.5 \times 10^{-4} = 7.5 \times 10^{-4}$ Allow calculation shown in one step. No TE on incorrect values Allow answers not in standard form	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
10(c)(i)	An answer that makes reference to the following points: - starch (1) - blue-black to colourless (1)	Allow blue or black to colourless Do not award light blue M2 depends on M1	(2)



Question Number	Acceptable Answer	Additional Guidance	Mark
10(c)(ii)	- moles thiosulfate used in titration (1) - moles unreacted iodine in flask (1) - moles of iodine that reacted with 10.0 cm³ vitamin C tablet solution (1) and (therefore) moles of ascorbic acid in 10.0 cm³ vitamin C tablet solution - moles of ascorbic acid in 250 cm³ solution (1 tablet) (1) - mass of ascorbic acid in 1 tablet (1) - expected mass of ascorbic acid in 1 tablet (1) and the label is wrong (as there is too little vitamin C in each tablet) or percentage of ascorbic acid in 1 tablet and the label is wrong (as there is too little vitamin C in each tablet)	<u>Example of calculation</u> $= 14.40 \times 0.100 \div 1000 = 1.44 \times 10^{-3} / 0.00144$ $= \frac{1.44 \times 10^{-3}}{2} = 7.2 \times 10^{-4} / 0.00072$ $= 7.5 \times 10^{-4} - 7.2 \times 10^{-4}$ $= 3.00 \times 10^{-5} / 0.00003$ $= 3.00 \times 10^{-5} \times 25 = 7.5 \times 10^{-4} / 0.00075$ $= 7.5 \times 10^{-4} \times 176 = 0.132 \text{ (g)}$ Expected mass of ascorbic acid in tablet = $6 / 100 \times 2.5 = 0.15 \text{ g}$ (which is greater than 0.132 g) Percentage = $0.132 \div 2.50 \times 100 = 5.28\%$ Calculations for MP4 and MP5 can be done in either order Correct answer without working scores 6 TE at all stages	(6)

(Total for Question 10 = 14 marks)
TOTAL FOR PAPER = 60 MARKS



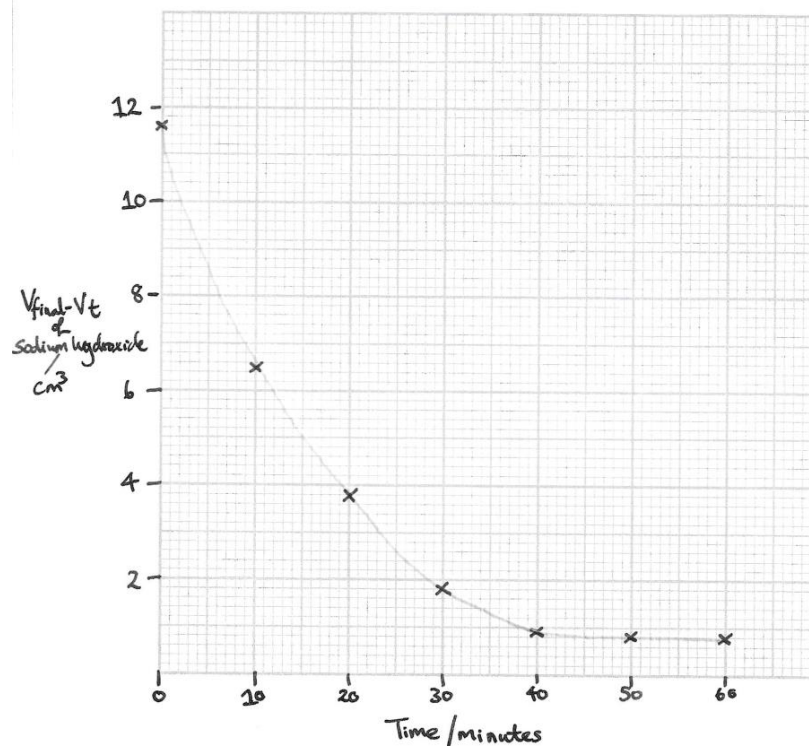
Question Number	Answer	Additional Guidance	Mark
10(a)(i)	An explanation that makes reference to the following points: - to stop / freeze / quench the reaction (1) - to allow time for the titration to be carried out (1)	Allow to prevent further hydrolysis/negligible reaction Ignore reference to cooling the reaction Ignore prevention of evaporation Ignore just slow the reaction Accept to prevent change/negligible change in concentration of reactants / products Allow so the concentration can be found at that time	(2)

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	An explanation that makes reference to the following points: - to ensure the hydrolysis / reaction reaches equilibrium (1) - so the maximum amount of carboxylic acid (formed) can be determined (1)	Allow hydrolysis reaction goes to completion Do not award reference to oxidation Allow reference to final equilibrium/at the end for maximum	(2)



Question Number	Answer	Additional Guidance	Mark
10(b)(i)	- both axes labelled with units with time on horizontal axis (1) - suitable scale where points cover at least half the available space horizontally and vertically (1) - all points plotted correctly and line of best fit shown (1)	Line of best fit to be with ± 2 small square of plotted points Do not award a line that goes up by 1 small square after 60 minutes	(3)

Exemplar graph

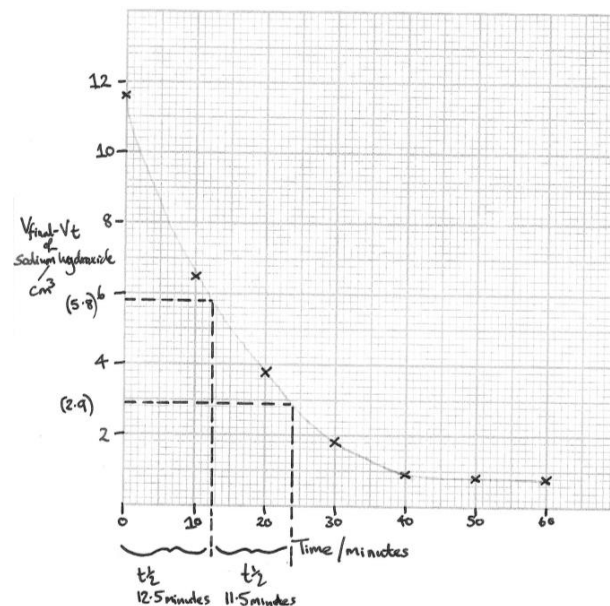


Question Number	Answer	Additional Guidance	Mark
10(b)(ii)	An explanation that makes reference to any two of the following points: • V_{final} is proportional to concentration of / amount of ester initially plus the acid catalyst (1) • $V_{\text{final}} - V_{\text{t}}$ is proportional to concentration of / amount of ester at each time / at t (1) • the concentration (of NaOH) does not change (so the graph would be a straight line) (1)		(2)



Question Number	Answer	Additional Guidance	Mark
10(b)(iii)	An answer that makes reference to the following points - first half-life correctly shown on graph and value determined (1) - second half-life correctly shown on graph and value determined (1)	Check the graph that 6 and 3 are not used Allow values between 11 and 13 (mins)	(2)

Exemplar graph



Penalise lack of working on graph once only

Question Number	Answer	Additional Guidance	Mark
10(b)(iv)	An answer that makes reference to the following point: first order and (as) half-lives are constant	Standalone mark No TE from half life values	(1)



Question Number	Answer	Additional Guidance	Mark
10(c)	An answer that makes reference to the following points: - Rate = $k [\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3][\text{OH}^-]$ (1) - as slow step involves 1 (mol) of ethyl ethanoate and 1 (mol) of OH^- ions (1)	Allow name or any correct structure of ester in rate equation Allow $\text{C}_4\text{H}_8\text{O}_2$ for ethyl ethanoate Allow any suitable alkali such as NaOH Allow r for rate Allow only 1 mol of each reactant in the rate determining step Ignore just that step 1 is the rate determining step Ignore just that they are both first order No TE on incorrect rate equation M2 dependent on M1 or near miss	(2)

(Total for Question 10 = 14 marks)



Question Number	Answer	Additional Guidance	Mark
7(a)	An explanation that makes reference to two of the following points: • (warmth) to allow for (all) the ethanol to evaporate • (24 hr) to allow (time for) the ethanol to fully react / fully oxidise • (To allow full oxidation of the ethanol) to ethanoic acid	(1) Ignore to speed the reaction up Ignore activation energy Do not award to evaporate the acidified dichromate(VI) (1) Allow the reaction goes to completion Allow all of ethanol reacts (1) Allow to ensure there is no ethanol / ethanal left ‘To allow time for all the ethanol to react to form ethanoic acid’, scores P2 and P3	(2)



Question Number	Answer	Additional Guidance	Mark
7(b)(i)	- calculation of moles of thiosulfate (1) - deduction of moles of iodine (1) - deduction of moles of acidified dichromate(VI) that reacted to form iodine (1) - calculation of moles of acidified dichromate(VI) that reacted with ethanol (1) - deduction of moles of ethanol in 5 cm³ sample (1)	<u>Example of calculation</u> $(32.70 \div 1000) \times 0.0220 = 7.194 \times 10^{-4} \text{ (mol)}$ $7.194 \times 10^{-4} \div 2 = 3.597 \times 10^{-4}$ $3.597 \times 10^{-4} \div 3 = 1.199 \times 10^{-4} \text{ (mol)}$ $[(10.0 \div 1000) \times 0.078] = 7.80 \times 10^{-4}$ $7.80 \times 10^{-4} - 1.199 \times 10^{-4} = 6.601 \times 10^{-4} \text{ (mol)}$ $6.601 \times 10^{-4} \times (3 \div 2)$ $= 9.9015 \times 10^{-4} / 9.90 \times 10^{-4} \text{ (mol)}$ Allow TE throughout Ignore SF except 1SF Correct answer without working scores 5	(5)



Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	- calculation of moles of ethanol in 250 cm³ of diluted drink (1) - calculation of concentration of alcoholic drink in mol dm⁻³ (1) - calculation of concentration of alcoholic drink in g dm⁻³ (1)	<u>Example of calculation</u> $9.9015 \times 10^{-4} \times (250 \div 5) = 0.049508 \text{ (mol)}$ $0.049508 \div (20 \div 1000) = 2.4754 \text{ (mol dm}^{-3}\text{)}$ $2.4754 \times 46 = 113.87 / 114 \text{ (g dm}^{-3}\text{)}$ Allow TE throughout including from part bi Ignore SF except 1SF Correct answer without working scores 3	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)	An answer that makes reference to the following points: - repeat the whole experiment / set up more than one version of the experiment and run concurrently (1) - take more than one sample / smaller samples (so more than one titration can be carried out) (1)	Do not allow just repeat the titration If no other mark is scored allow repeat the titration and calculate a mean / repeat the titration until concordant results are obtained Ignore starch / indicator	(2)



Question Number	Answer	Additional Guidance	Mark
7(d)	An answer that makes reference to the following points: M1 reason to support change • heating under reflux will speed up the reaction or • less chance of incomplete reaction with heating under reflux M2 reason to remain unchanged • might be other (less volatile substances) that could also be oxidised by the dichromate(VI) or • greater risk of uncontrolled reaction associated with heating under reflux or • greater risk of some of the ethanol evaporating with reflux	(1) (1) Ignore the ethanol and the ethanoic acid produced might react to form an ester Ignore greater risk of flammability Allow some ethanol may escape from the reflux condenser before it is oxidised	(2)

(Total for Question 7 = 14 marks)



Question Number	Answer	Additional Guidance	Mark
9(a)(i)	An answer that makes reference to the following points: • carry out in a fume cupboard (1) • SO₂ is toxic / poisonous (1)	Allow in a well-ventilated laboratory Ignore references to handling safely etc Allow SO₂ is corrosive Allow reference to SO₂ issues for breathing difficulties e.g. asthma Allow reference to gases/fumes for SO₂ Ignore acidic/harmful/irritant	(2)

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	An explanation that makes reference to the following points: • SO₂ form acids when dissolved (1) • so the titre value would be greater (than expected) / results would (appear to) show more (tartaric) acid (than was present in the wine) (1)	Allow SO₂ is acidic Allow SO₂ reacts with the NaOH Ignore CO₂ M2 is dependent upon M1 or a near miss such as the titre value is increased because of greater acidity or the reaction of dissolved gases with NaOH	(2)



Question Number	Answer	Additional Guidance	Mark
9(a)(iii)	A calculation that makes reference to the following points: - calculation of amount of NaOH and amount of tartaric acid (1) - calculation of amount of tartaric acid in mol dm⁻³ (1) - calculation of amount of tartaric acid in g dm⁻³ (1)	$(20.6 \div 1000) \times 0.100 = 2.06 \times 10^{-3} \text{ (mol)}$ $= 2.06 \times 10^{-3} \div 2 = 1.03 \times 10^{-3} \text{ (mol)}$ $1.03 \times 10^{-3} \div (20 \div 1000) = 0.0515 \text{ (mol dm}^{-3}\text{)}$ $= 0.0515 \times 150 = 7.725 \text{ (g dm}^{-3}\text{)}$ Accept step 3 carried out before step 2 Ignore intermediate units even if incorrect Ignore SF except 1SF TE throughout	(3)

Question Number	Answer	Additional Guidance	Mark
9(a)(iv)	An explanation that makes reference to the following points: - the titre value includes the volume of the air bubble (as well as sodium hydroxide solution) (1) - so the titre value would be greater (than expected) (1)	Allow some alkali/solution is used to fill the air bubble/ burette tip/burette jet M2 is dependent upon M1 or a near miss	(2)



Question Number	Answer	Additional Guidance	Mark
9(b)(i)	An explanation that makes reference to the following points: • calculation of amount of iodine (1) • calculation of concentration of SO₂ in mol dm⁻³ (1) • calculation of concentration of SO₂ in g dm⁻³ (1) • calculation of concentration of SO₂ in mg dm⁻³ and comment regarding allowable level (1)	(11.80 ÷ 1000) × 0.01 = 1.18 × 10⁻⁴ / 0.000118 (mol) 1.18 × 10⁻⁴ ÷ (50 ÷ 1000) = 2.36 × 10⁻³ / 0.00236 (mol dm⁻³) 2.36 × 10⁻³ × 64.1 = 0.15128 (g dm⁻³) = 0.15128 × 1000 = 151 (mg dm⁻³) so below maximum permitted level Allow just 'so ok/suitable' or 151 < 200 for comment Accept calculations in steps 2 to 4 in any order Accept calculation carried out in reverse order, i.e. from permitted mass to moles Ignore intermediate units Final answer without working scores (4) Allow use of 64 for M_r of SO₂ Allow final answer in g dm⁻³ if permitted maximum converted to g dm⁻³ Ignore SF except 1SF TE throughout provided that the numbers are carried forward	(4)

Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	An explanation that makes reference to the following points: • to produce CO₂ (1) • which forms a blanket / layer (on surface of solution) (1)	Allow CO₂ is denser / heavier than air (so stops escape of SO₂) Allow SO₂ cannot get past the (blanket of) CO₂	(2)

(Total for Question 9 = 15 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
6(a)	23.15 and 23.55 and 23.20 completed in table	All three titres must be shown to 2 D.P.	(2)
	✓ beneath titres 1 and 3 and mean titre = 23.18 (cm³)	Allow 23.2 or 23.175 (cm ³)	

Question Number	Acceptable Answers	Additional Guidance	Mark
6(b)	(From)(pale) pink/purple (to) colourless	Both colours needed for the mark	(1)
		Do not award mauve or magenta or violet for pink/purple	
		Ignore references to 'clear'	

Question Number	Acceptable Answers	Additional Guidance	Mark
6(c)	- calculation of moles of MnO_4^- in 25.0 cm^3 (1) - calculation of moles of NO_2^- in mean titre (1) - calculation of moles of NO_2^- in 250 cm^3 (1) - calculation of molar mass (1)	Example of calculation Moles $\text{MnO}_4^- = \frac{0.02(00) \times 25.0}{1000}$ $= 5(.00) \times 10^{-4} / 0.0005(00)$ (mol) Moles $\text{NO}_2^- = 2.5 \times \text{moles } \text{MnO}_4^-$ in mean titre $= 1.25 \times 10^{-3} / 0.00125 \text{ (mol)}$ Moles NO_2^- in $250 \text{ cm}^3 =$ moles NO_2^- in mean titre $\times \frac{250}{\text{mean titre from (a)}}$ $= 1.25 \times 10^{-3} \times \frac{250}{23.18}$ $= 0.013481449$ $= 0.0135 \text{ (mol)}$ Allow TE on mean titre from (a) Ignore SF except 1 SF Molar mass $= 2 \times \frac{1.15}{0.0135}$ $= 170.3703704 \text{ (g mol}^{-1}\text{)}$ $= 170.4 \text{ (g mol}^{-1}\text{)}$	(5)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(d)	$2\text{MnO}_4^- + 5\text{NO}_2^- + 6\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 3\text{H}_2\text{O}$ - evidence of multiplying 1st equation by 2 and 2nd equation by 5 - overall equation correct with H^+ and H_2O and $\text{e}^{(-)}$ cancelled as appropriate	Each of the following equations score (1) mark overall: $2\text{MnO}_4^- + 5\text{NO}_2^- + 16\text{H}^+ + 5\text{H}_2\text{O}$ $\rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 8\text{H}_2\text{O} + 10\text{H}^+$ OR $2\text{MnO}_4^- + 5\text{NO}_2^- + 6\text{H}^+ + 5\text{H}_2\text{O}$ $\rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 8\text{H}_2\text{O}$ OR $2\text{MnO}_4^- + 5\text{NO}_2^- + 16\text{H}^+$ $\rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 10\text{H}^+ + 3\text{H}_2\text{O}$ Ignore state symbols, even if incorrect Allow multiples	(2)

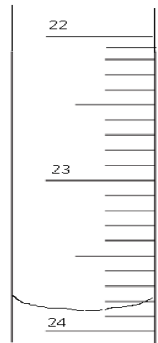
Question Number	Acceptable Answers	Additional Guidance	Mark
6(e)	An explanation that makes reference to the following: Either - the (calculated) value of x would be too high (1) - The moles of MgCO_3 would be too low / the moles of $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$ would be too low / the M_r of $\text{Mg}(\text{NO}_2)_2 \cdot x\text{H}_2\text{O}$ would be too high (1) Or (So) the (calculated) value of x would be unchanged (so this does not explain the discrepancy) (1) - Only a small amount/mass of MgCO_3 would dissolve because it is very slightly soluble (1)	Allow 'amount' or 'mass' for 'moles' MP2 depends on MP1 MP2 depends on MP1	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(f)	An answer that makes reference to the following points: - the MgCO_3 would decompose / the residue would contain NaNO_2 / the residue would contain (the excess) Na_2CO_3 (1) (so) the (proposed) method is not valid / appropriate / suitable (1)	Ignore references to just 'impurities' M2 dependent on M1	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(g)	An answer that makes reference to the following point: heat (the sample) to constant mass	Allow repetition of heating and weighing until there is no change in mass (of the sample) Ignore references to 'brown gas' etc	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
6(h)	An answer that makes reference to the following points: - use a larger mass (of the hydrated salt) (1) - Use a balance that weighs to 3 D.P. (rather than 2 D.P.) (1)	Ignore references to repeat measurements Allow statements such as 'use a balance that weighs to more decimal places' / 'greater resolution' / 'a more precise/sensitive balance' Do not allow 'more accurate'	(2)

(Total for Question 6 = 17 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(i)	- bottom of meniscus between 23.8 and 23.9 (cm³) (1) - meniscus curved downwards (1)	<u>Example of diagram</u>  Ignore shading below the meniscus Do not award M2 if there is shading above the meniscus	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(ii)	An explanation that makes reference to the following points: 23.15 (cm³) should be used as it is the mean of the concordant titres / titres 2 and 4 / 23.10 and 23.20 (cm³) (1) 23.43 (cm³) should not be used as it includes the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm³) (1)	Allow other descriptions of concordant e.g. titres within 0.1 / 0.2 cm³ Allow $(23.1(0) + 23.2(0))/2 = 23.15$ (cm³) Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm³) should be used / are used (in the mean) Allow the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm³) should not be used / are used (in the mean)	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(iii)	calculation of percentage uncertainty	<u>Example of calculation</u> $\frac{2 \times 0.05}{23.20} \times 100$ $= (\pm)0.431 / 0.43 / 0.4$ (%) Ignore SF including 1 SF Correct answer with no working scores (1)	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
7(a)(iv)	- calculation of moles of MnO_4^- (1) - calculation of moles $\text{C}_2\text{O}_4^{2-}$ in 25.0 cm^3 (1) - calculation of moles $\text{C}_2\text{O}_4^{2-}$ in 1.00 dm^3 (1) - calculation of y to nearest whole number (1)	<u>Example of calculation</u> moles $\text{MnO}_4^- = 23.15 \times 0.0203/1000$ $= 0.00046995 / 4.6995 \times 10^{-4} \text{ (mol)}$ moles $\text{C}_2\text{O}_4^{2-}$ in $25.0 \text{ cm}^3 = 4.6995 \times 10^{-4} \times 5/2$ $= 0.0011749 / 1.1749 \times 10^{-3} \text{ (mol)}$ TE on moles MnO_4^- moles $\text{C}_2\text{O}_4^{2-}$ in $1.00 \text{ dm}^3 = 1.1749 \times 10^{-3} \times \frac{1000}{25.0}$ $= 0.046995 / 4.6995 \times 10^{-2} \text{ (mol)}$ TE on moles $\text{C}_2\text{O}_4^{2-}$ in 25.0 cm^3 Ratio moles salt : moles $\text{C}_2\text{O}_4^{2-}$ $= 0.0235 : 0.046995 = 1 : 1.9998$ $y = 2$ TE on moles $\text{C}_2\text{O}_4^{2-}$ in 1.00 dm^3 Alternative method for M3 and M4 moles salt in $25.0 \text{ cm}^3 = 0.0235 \times 25.0/1000$ $= 5.875 \times 10^{-4} \text{ (1)}$ Ratio moles salt : moles $\text{C}_2\text{O}_4^{2-}$ $= 5.875 \times 10^{-4} : 1.1749 \times 10^{-3}$ $= 1 : 1.9998$ $y = 2$ TE on moles salt and $\text{C}_2\text{O}_4^{2-}$ in $25.0 \text{ cm}^3 \text{ (1)}$ Ignore SF in working except 1 SF Correct answer with no working scores (1) Allow M4 for correct answer using charges on ions	(4)



Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(i)	- calculation of mol of anhydrous salt (1) - calculation of mol H₂O (1) - calculation of z to nearest whole number (1)	<u>Example of calculation</u> mol anhydrous salt = $2.96/218.1$ = $0.013572 / 1.3572 \times 10^{-2}$ (mol) TE on M_r of anhydrous salt from value of y in (a)(iv) or an assumed value of y Allow 0.013578 from M_r 218 mol H₂O (= $0.45/18$) = $0.025 / 2.5 \times 10^{-2}$ (mol) Ratio mol salt : mol H₂O = 0.013572 : 0.025 = 1 : 1.842 z = 2 TE on moles anhydrous salt and moles H₂O Ignore SF in working except 1 SF Correct answer with some working scores (3) Penalise y and z not given to nearest whole number once only in (a)(iv) and (b)(i) Allow alternative correct methods	(3)



Question Number	Acceptable Answers	Additional Guidance	Mark
7(b)(ii)	An answer which includes the following points: Crystals jumped out of crucible - value of z increases and because it appears that more mass / mol / water is lost (than expected) (1) (this can be prevented by) placing a lid on the crucible or heat more gently / carefully (1) Not all water of crystallisation lost - less mass / mol / water is lost (than expected) (1) (this can be prevented by) heating to constant mass or description of heating to constant mass (1) - so this accounts for the lower value of z / value of z decreases (1)	Ignore just 'loss in mass / mol' Stand alone mark Allow just 'cover the crucible' Ignore use an electrical heater / larger crucible / evaporating basin / conical flask / test tube etc Do not award add anti-bumping granules Stand alone mark Ignore just 'heat for longer' Do not award the idea of repeating the experiment / using a drying agent Conditional on M3	(5)

(Total for Question 7 = 17 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)	A description that makes reference to the following points: (remove colourless solution by) rinsing with sulfuric acid (of concentration 2.00 mol dm^{-3}) - in order to prevent dilution (of acid sample) / keep acid concentration the same	(1) Allow rinse with deionised / distilled water followed by (2.00 mol dm^{-3}) sulfuric acid (1) Allow other substances left in the pipette might react (with any of the other reactants or products) M2 dependent on M1	(2)

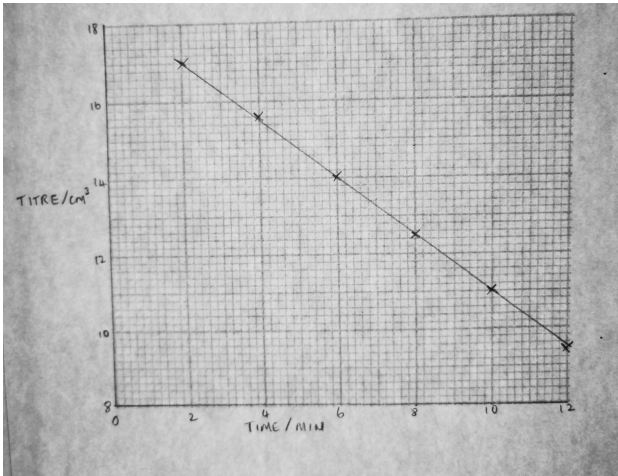
Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An explanation that makes reference to the following points: stopping the reaction in order to ensure there is no (further) change in concentration (before the titration is carried out) /	(1) Allow slowing down the reaction / freezing the reaction Ignore references to stopping / freezing an equilibrium (1) Ignore to ensure the titration is accurate Ignore references to stopping an equilibrium	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An answer that makes reference to the following points: - sodium hydrogencarbonate (solution) / NaHCO_3 / potassium hydrogen carbonate / KHCO_3 - correct equation to match compound	(1) Accept sodium / potassium carbonate (solution) / Na_2CO_3 / K_2CO_3 (1) Ignore state symbols even if incorrect If both name and formula are given, they must match e.g. $2\text{NaHCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{CO}_2 + 2\text{H}_2\text{O}$ / $2\text{KHCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{CO}_2 + 2\text{H}_2\text{O}$ / $\text{NaHCO}_3 + \text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Na}^+$ / $\text{KHCO}_3 + \text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{K}^+$ / $\text{KHCO}_3 + \text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{K}^+$ / $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ / $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$ / $\text{Na}_2\text{CO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{CO}_2 + \text{H}_2\text{O}$ / $\text{K}_2\text{CO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + \text{CO}_2 + \text{H}_2\text{O}$ / $\text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ / $\text{H}_2\text{SO}_4 + \text{CO}_3^{2-} \rightarrow \text{SO}_4^{2-} + \text{H}_2\text{O} + \text{CO}_2$	(2)



Question Number	Answer	Additional Guidance	Mark
4(c)	An explanation that makes reference to two of the following points: - risk depends on both hazard and amount of a substance (1) (only a) small amount of it / iodopropanone is formed (1) (most of) it / iodopropanone remains in solution (1)	Allow as reaction runs for only a short amount of time Allow it / iodopropanone is not a gas / is a liquid / has a high boiling point / not volatile Ignore harmful fumes Ignore iodopropanone is a solid	(2)

Question Number	Answer	Additional Guidance	Mark
4(d)	An answer that makes reference to the following points: - calculation of moles of iodine (1) - calculation of moles of propanone (1) - show moles propanone are much greater than iodine / propanone is in great excess and so there is a negligible / very small change in the concentration of propanone (1) - change in rate is due only to the changing concentration of iodine (1)	<u>Example of calculation</u> (Moles of I₂) = (0.0500 × 0.0200) = 1.00 × 10⁻³ Ignore SF (Moles of propanone) = 0.0250 × 2.00 = 0.0500 (mol) Ignore SF 0.0500 >> 1.00 × 10⁻³ (so order is wrt I₂) Ignore just propanone is in excess Allow iodine is a limiting factor Ignore the sulfuric acid throughout	(4)

Question Number	Answer	Additional Guidance	Mark
4(e)(i)	An answer that makes reference to the following points: - axes labelled including units and suitable scale, where points cover at least half the available space - points plotted correctly (allow $\pm$ a square) and straight line of best fit	Allow volume or vol for titre <u>Example of graph</u> 	(2)

Question Number	Answer	Additional Guidance	Mark
4(e)(ii)	An answer that makes reference to the following point: as the titre / volume (of sodium thiosulfate solution) is (directly) proportional to the concentration (of iodine)		(1)

Question Number	Answer	Additional Guidance	Mark
4(e)(iii)	An answer that makes reference to the following points: - order with respect iodine = 0 - gradient remains constant	(1) (1) Allow straight line / linear (with a negative gradient) / the gradient is independent of the concentration M2 dependent on M1	(2)

(Total for Question 4 = 17 marks)



Question Number	Answer	Additional Guidance	Mark
8(a)	colourless to (permanent pale/light) pink	Do not award purple for pink	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	- double C=O bond on left and right hand side - rest of diagram	(1) (1)	(2)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	(+) 3	Allow 3+ / +III / III+ / III / three Ignore working out Do not award ± 3	(1)

Question Number	Answer	Additional Guidance	Mark
8(c)	to provide the hydrogen ions (needed as a reactant in the balanced equation) / to prevent formation of MnO ₂ / to prevent (brown) precipitate forming	Allow reaction needs acidic conditions Do not award 'acts as a catalyst' / just 'ensures reaction go to completion'	(1)

Question Number	Answer	Additional Guidance	Mark
8(d)	- both platinum symbols and salt bridge (1) - rest of diagram (1)	$\text{Pt(s)} \mid \text{C}_2\text{O}_4^{2-}(\text{aq}), 2\text{CO}_2(\text{g}) \parallel [\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq})], [\text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O(l)}] \mid \text{Pt(s)}$ Allow solid lines for salt bridge Allow half cells shown correctly on opposite side Ignore omission of square brackets / state symbols if neither marked scored allow 1 mark for all four ‘redox’ species in ROOR order, separated by commas or dashed lines, but not solid lines	(2)

Question Number	Answer	Additional Guidance	Mark																														
8(e)(i)	• titres calculated and both ticks correct (1) • mean calculated (1)	<table><tr><th>Run</th><th>Trial</th><th>One</th><th>Two</th><th>Three</th></tr><tr><td>Final volume / cm³</td><td>17.50</td><td>34.10</td><td>17.20</td><td>34.10</td></tr><tr><td>Initial volume /cm³</td><td>0.00</td><td>17.30</td><td>0.00</td><td>17.20</td></tr><tr><td>Titre / cm³</td><td>17.50</td><td>16.80</td><td>17.20</td><td>16.90</td></tr><tr><td>Concordant titres (✓)</td><td></td><td>✓</td><td></td><td>✓</td></tr><tr><td>Mean titre /cm³</td><td colspan="4">16.85</td></tr></table> Both titres to 2 dp mean = (16.90+16.80)÷2 = 16.85 (cm³) allow TE for M2 for mean of One, Two and Three = 16.97 (cm³)	Run	Trial	One	Two	Three	Final volume / cm ³	17.50	34.10	17.20	34.10	Initial volume /cm ³	0.00	17.30	0.00	17.20	Titre / cm ³	17.50	16.80	17.20	16.90	Concordant titres (✓)		✓		✓	Mean titre /cm ³	16.85				(2)
Run	Trial	One	Two	Three																													
Final volume / cm ³	17.50	34.10	17.20	34.10																													
Initial volume /cm ³	0.00	17.30	0.00	17.20																													
Titre / cm ³	17.50	16.80	17.20	16.90																													
Concordant titres (✓)		✓		✓																													
Mean titre /cm ³	16.85																																

Question Number	Answer	Additional Guidance	Mark
8(e)(ii)	- calculation of moles of $\text{Na}_2\text{C}_2\text{O}_4(\text{aq})$ (1) - calculation of moles of KMnO_4 in titre (1) - calculation of moles of KMnO_4 in 100 cm^3 (1) - calculation of M_r for KMnO_4 (1) - calculation of mass of 1 tablet in mg to 2 or 3SF (1)	<u>Example of calculation</u> $(25.0 \div 1000) \times 0.200 = 0.005 / 5.00 \times 10^{-3} (\text{mol})$ $5.00 \times 10^{-3} \times 2 \div 5 = 0.002 / 2.00 \times 10^{-3} (\text{mol})$ $2.00 \times 10^{-3} \times (100 \div 16.85) = 0.011869 (\text{mol})$ 158 $0.011869 \times 158 = 1.8754 \text{ g}$ $(1.8754 \div 5) \times 1000 = 375.07 \text{ mg} = 380 / 375 (\text{mg})$ Correct answer with or without working scores 5 marks 0.38 g scores 4 marks (M5 not awarded) TE at each stage and on mean titre 379 mg from 0.012 scores (5)	(5)

Question Number	Answer	Additional Guidance	Mark
8(e)(iii)	An explanation that makes reference to the following points (reaction is slow initially) as MnO_4^- and $\text{C}_2\text{O}_4^{2-}$ are (both) negative (ions) so will repel (each other) (1) - when (sufficient) Mn^{2+} ions form they (auto) catalyse the reaction (1) Mn^{2+} ions will reduce MnO_4^- ions (as $E^\ominus$ is more negative) forming Mn^{3+} ions OR $\text{MnO}_4^- + 8\text{H}^+ + 4\text{Mn}^{2+} \rightarrow 5\text{Mn}^{3+} + 4\text{H}_2\text{O}$ ($E^\ominus = +0.02\text{V}$) (1) Mn^{3+} ions then oxidise $\text{C}_2\text{O}_4^{2-}$ ions (reforming Mn^{2+}) (as $E^\ominus$ is more positive) OR $\text{C}_2\text{O}_4^{2-} + 2\text{Mn}^{3+} \rightarrow 2\text{Mn}^{2+} + 2\text{CO}_2$ ($E^\ominus = +0.85\text{V}$) (1)	Allow 'heat is required to overcome high activation energy when catalyst is absent' Allow Mn^{2+} ions will react with MnO_4^- ions as $E^\ominus$ is more negative Allow Mn^{3+} ions then react with $\text{C}_2\text{O}_4^{2-}$ ions (reforming Mn^{2+}) as $E^\ominus$ is more positive May be shown in equations and / or by calculating $E^\ominus$	(4)

(Total Question 8 = 18 marks)

TOTAL FOR PAPER = 90 MARKS

Question Number	Answer	Additional Guidance	Mark
3(a)(i)	A description that makes reference to two of the following: - rinse the glass rod (into the beaker) or rinse beaker (several times) or rinse the funnel (1) - transfer the washings to the (volumetric) flask (1)	Ignore reference to weighing	(2)
Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	An answer that makes reference to: removal of the excess solution will remove some of the dissolved sodium hydroxide (so that the exact concentration will be unknown) or the concentration won't be known because the total volume will be more than 250cm³	Allow 'not just removing deionised water' Ignore just 'decrease the concentration'	(1)



Question Number	Answer	Additional Guidance	Mark
3(b)(i)	An answer that makes reference to any two of the following: - the tip of the burette must be filled with solution (1) - remove the funnel (1) - ensure the burette is held vertical (1) - eyes are level with the bottom of the meniscus (1)	Allow 'jet space' for tip Allow just 'remove air bubbles' Allow 'upright' for vertical Allow 'take readings at eye-level' Allow 'read from the bottom of the meniscus' Ignore reference to clamping and use of stand	(2)

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An answer that makes reference to the titre will be larger because either there is water left in the burette or the sodium hydroxide solution will be diluted/lower	Allow the titre will be larger because the burette should have been rinsed with sodium hydroxide	(1)



Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An assessment that includes • (M1) the vertical part of the graph is at ~7 - 10/ the mid-point is at 8.5-8.8 (1) • (M2) the mid-point of the colour change of methyl red is 5.1 (1) • (M3) pH range of methyl red does not lie (completely) within the vertical range of the pH curve (so it is not suitable) (1) • (M4) the colour change will be complete before the equivalence point is reached (1)	Allow 'equivalence point/end-point' for 'the vertical part of the graph/ the mid-point' Allow methyl red changes colour in the range/ has a pH range 4.2 - 6.3/ pK_{in} 5.1 Allow, after stating M1 and M2, 'this means that methyl red is unsuitable' Allow end-point/neutralisation point for equivalence point Do not award colour change to red Ignore references to choice of other indicators	(4)

Question Number	Answer	Additional Guidance			Mark
3(c)(ii)	An answer that includes two ticks and two crosses as shown	Indicator	pH range	Tick or Cross	(1)
		Bromocresol purple	5.2 - 6.8	x	
		Thymol blue	8.0 - 9.6	✓	
		Thymolphthalein	8.3 - 10.6	✓	
		Alizarin yellow R	10.1 - 13.0	x	
		Do not award blank boxes for (x)			



Question Number	Answer	Additional Guidance					Mark
3(d)(i)	completed table	Exemplar table					(1)
		Titration number	1	2	3	4	
		Final burette reading / cm ³	13.00	25.50	37.90	50.00	
		Initial burette reading / cm ³	0.25	13.00	25.50	37.90	
		Titre / cm ³	12.75	12.50	12.40	12.10	
		Concordant titres (✓)		✓	✓		
		COMMENT Allow 12.5/ 12.4 /12.1 Do not award additional ticks					

Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	calculation of percentage measurement uncertainty	<u>Example of calculation</u> $\% = ((0.05 \times 4) \div 12.40 \times 100)$ $= 1.6\% / 1.61\% / 2\%$ Ignore SF Do not award 1.65% rounded to 2%	(1)

Question Number	Answer	Additional Guidance	Mark
3(e)	(M1) calculation of number of moles of NaOH weighed out (1) (M2) concentration of NaOH solution (1) (M3) number of moles of NaOH in titre (1) (M4) molar concentration of CH₃COOH solution (1) (M5) concentration in g dm⁻³ of CH₃COOH solution to 2/3SF (1)	<u>Example of calculation</u> n(NaOH) = $3.80 \div 40 = 0.095 / 9.5 \times 10^{-2}$ (mol) [NaOH] = $0.095 \div 0.250 = 0.38$ (mol dm⁻³) n(NaOH) = 0.38×0.0119 = $0.004522 / 4.522 \times 10^{-3}$ (mol) [CH₃COOH] = $4.522 \times 10^{-3} \div 0.025$ = 0.18088 (mol dm⁻³) [CH₃COOH] = 0.18088×60 = 10.8528 (g dm⁻³) = $10.9 / 11$ (g dm⁻³) Do not award 10.90 (g dm⁻³) Correct answer without working scores (5) Accept steps in a different order, e.g. moles x 60 before dividing by 0.025 TE throughout Penalise incorrect units in M5 only	(5)

(Total Question 3 = 18 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
8(a)	Any one from: Catalyst / speeds up reaction / increases rate / increases rate of attainment of equilibrium / lowers activation energy	Ignore any mention of protonation or mechanism for catalysis Do not award additional incorrect types of reaction	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(i)	- calculation of moles of H^+ in 25.0 cm^3 (1) - calculation of moles of H^+ in 250 cm^3 flask (1)	Ignore SF throughout 8(b)(i) to 8(c)(ii) except 1 SF, which should be penalised once only <u>Example of calculation:</u> (moles NaOH = $0.200 \times \frac{23.60}{1000}$) = 0.00472 (mol) (= mol H^+ in 25.0 cm^3) (= 10×0.00472) = 0.0472 (mol) (in 250 cm^3) Allow TE for M2 on moles of NaOH Correct answer with or without working scores 2 marks	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)(ii)	subtracts moles of H^+ in HCl from answer to (b)(i)	<u>Example of calculation:</u> $0.0472 - 0.00400 = 0.0432 \text{ (mol)}$ Allow TE on answer to part (b)(i)	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark
8(c)(i)	calculation of moles of CH_3COOH that have reacted	<u>Example of calculation:</u> $(0.105 - 0.0432) = 0.0618$ Allow TE on part (b)(ii) unless negative value	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(c)(ii)	- calculation of equilibrium moles of $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ (1) - calculation of equilibrium moles of $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_3$ (1) - calculation of equilibrium moles of H_2O (1)	<u>Example of calculation:</u> $0.0800 - 0.0618 = 0.0182$ 0.0618 $0.111 + 0.0618 = 0.1728$ Allow TE on answer to part (c)(i) unless negative value	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(d)(i)	$(K_c =) \frac{[\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_3][\text{H}_2\text{O}]}{[\text{CH}_3\text{COOH}][\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}]}$	IGNORE state symbols even if incorrect Do not award round brackets	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark
8(d)(ii)	An explanation that makes reference to the following points: - Same number of moles/molecules on both sides of the equation (1) (so) volume / V cancels in K_c expression (1)	2 marks could be scored by a correct mathematical expression showing V or dm^3 cancel Allow same number of terms on top and bottom of K_c expression Allow units cancel out Allow "all divided by the same volume"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(d)(iii)	- calculates value of K_c (1) - final value of K_c quoted to 2 or 3 SF (1)	<u>Example of calculation</u> $K_c = \frac{(0.0618) \times (0.1728)}{(0.0432) \times (0.0182)} = 13.58241758$ $= 14 / 13.6 \text{ (no units)}$ Correct answer with no working gains full marks Ignore units No TE on wrong K_c expression	2



Question Number	Acceptable Answers	Additional Guidance	Mark
8(e)	An explanation that makes reference to the following points: - the equilibrium shifts to the left or the mixture absorbs carbon dioxide from the atmosphere (1) - so the mixture is (becoming more) acidic / the acid reforms (1)	Mark independently Allow no longer alkaline Do not award just "pH decreases"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(f)	An explanation that makes reference to the following points: - carry out / repeat experiment and leave for longer than a week (1) - the titre value / K_c value will remain unchanged (if equilibrium has been established) (1)	Ignore pH probes / checking pH Allow repeat experiment and check titres within first week Allow moles / concentration are unchanged Ignore just "results unchanged"	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
8(g)	An answer that makes reference to the following points: K_c value will be greater than that calculated in (d)(iii) (1) - because the (forward) reaction is endothermic or backward / reverse reaction is exothermic (1)	M2 depends on M1 Ignore References to the equilibrium position shifting to the right (with increasing temperature)	(2)

(Total for Question 8 = 19 marks)**TOTAL FOR PAPER = 120 MARKS**

Question Number	Answer	Mark
3(a)	The only correct answer is C (90.9 %) <i>A is not correct because this is the atom economy of one sodium stearate divided by stearin plus one sodium hydroxide which is then multiplied by 100</i> <i>B is not correct because this is the relative molecular mass of one sodium stearate divided by stearin and multiplied by 100</i> <i>D is not correct because this is the atom economy calculated for three sodium stearate molecules divided by stearin plus one sodium hydroxide</i>	(1)

Question Number	Answer	Mark
3(b)	The only correct answer is D (propane-1,2,3-triol) <i>A is not correct because the functional group provides the suffix in the name</i> <i>B is not correct because the alcohol group positions need to be indicated by a number</i> <i>C is not correct because three alcohol or hydroxyl groups are all aggregated in the suffix 'ol' and numbered before the suffix</i>	(1)

(Total for Question 3 = 2 marks)



Question Number	Answer	Mark
2(a)	The only correct answer is A (4-ethyloctane) <i>B is incorrect because the position of the ethyl group should be shown by counting in the direction that gives the lowest possible number</i> <i>C is incorrect because the longest carbon chain has 8 carbons</i> <i>D is incorrect because the longest carbon chain has 8 carbons and because the position of the alkyl group should be shown by counting in the direction that gives the lowest possible number</i>	(1)

Question Number	Answer	Mark
2(b)	The only correct answer is D (cracking) <i>A is incorrect because substitution would exchange atoms/groups in the reactant for other atoms/groups</i> <i>B is incorrect because reforming would produce branched/cyclic alkanes</i> <i>C is incorrect because fractional distillation would separate a mixture of alkanes</i>	(1)

Question Number	Answer	Mark
2(c)(i)	The only correct answer is C (homolytic bond fission to form free radicals) <i>A is incorrect because such bond fission would produce ions</i> <i>B is incorrect because the first step of the reaction produces free radicals by homolytic fission</i> <i>D is incorrect because the first step of the reaction produces free radicals</i>	(1)

Question Number	Answer	Additional Guidance	Mark
2(c)(ii)	$122.9 \div (122.9 + 80.9) \times 100$ or $122.9 \div (44.0 + (2 \times 79.9)) \times 100$ or $(122.9 \div 203.8) \times 100$ $= 60.304\%$	Allow $123 \div (123 + 81) = 60.29\%$ Award M1 only if final answer given as decimal 0.603 rather than % Allow TE for M2 for only one incorrect A_r value Ignore SF Correct answer with or without working scores (2)	(2)

Question Number	Answer	Mark
2(c)(iii)	The only correct answer is D (the reaction produces a mixture of organic products) <i>A is incorrect because bromine is very reactive</i> <i>B is incorrect because gaseous reactants do not necessarily give a poor yield</i> <i>C is incorrect because the kinetics of the reaction do not affect the yield</i>	(1)



Question Number	Answer	Additional Guidance	Mark
2(c)(iv)	Amount of 1-bromopropane (1)	$14.7/122.9 = 0.11961 \text{ (mol)}$	(3)
	So moles of propane required (1)	$(0.11961/31) \times 100 = 0.38584 \text{ (mol)}$	
	So volume of propane required to 2 or 3 SF (1)	$= 0.38584 \times 24.0 = 9.2601 \text{ (dm}^3\text{)}$ $= 9.3 / 9.26 \text{ (dm}^3\text{)}$ Allow $14.7/123 = 0.11951 \text{ (mol)}$ $(0.11951/31) \times 100 = 0.38552 \text{ (mol)}$ $= 0.38552 \times 24.0 = 9.2526 \text{ (dm}^3\text{)}$ $= 9.3 / 9.25 \text{ (dm}^3\text{)}$	
	Alternative route		
	Target mass of 1-bromopropane required to produce 14.7 g (with a 31.0% yield) (1)	$14.7 \times \frac{100}{31.0} = 47.4 \text{ g}$	
	Moles of propane required to produce the required mass of 1-bromopropane (1)	$\frac{47.4}{122.9} = 0.3857 \text{ (mol)}$	
	So volume of propane required to 2 or 3 SF (1)	$0.3857 \times 24.0 = 9.3 / 9.26 \text{ (dm}^3\text{)}$ Award (2) for a final answer of 0.890 / 0.89 (dm ³) (incorrect use of 31.0%) Answer assuming 100% yield scores (2) for final answer of 2.87 / 2.9 (dm ³) Penalise incorrect units in M3 Do not award M3 if Ideal Gas Eqtn used for propane volume Penalise incorrect rounding once only Correct answer to 2 or 3 SF with or without working scores (3)	

(Total Question 2 = 9 marks)



Question Number	Answer	Additional Guidance	Mark
7(a)(i)	An answer that makes reference to the following point: expel some solution (to remove the air bubble and suck up again with the tip of the pipette in the solution) or (fill pipette above the line and) expel some solution (to remove the bubble)	Allow gently tap the side of the pipette to move the air bubble to the top and out of the solution Do not award answers referring to opening taps Do not award inverting the pipette	(1)

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	calculation of maximum volume	<u>An example of calculation</u> $25.04 + 25.04 = 50.08 \text{ (cm}^3\text{)}$	(1)

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	- calculation using one 25 cm³ pipette twice - calculation using one 50 cm³ pipette and making a comparison	<u>An example of calculation</u> (1) % uncertainty = $(100 \times 0.08 \div 50)$ = 0.16 % (1) % uncertainty = $(100 \times 0.05 \div 50)$ = 0.1(0) % e.g. Difference = $0.16 - 0.10 = 0.06 \%$ or $0.16\% > 0.10\%$ TE on (a)(ii) Allow TE for M2 Ignore SF including 1SF	(2)



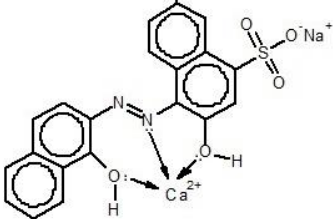
Question Number	Answer	Additional Guidance	Mark
7(b)(i)	unsuitable because the smallest volume you can measure is 10 cm^3	Allow unsuitable/No because 2 cm^3 is too small to measure in a 100 cm^3 measuring cylinder Allow unsuitable/No because the graduations are too big to measure such a small volume Allow unsuitable/No because the (percentage) uncertainty will be too large Allow unsuitable/No because the resolution is too low/is not precise enough Allow suitable/Yes because the volume doesn't have to be accurate and about 2 cm^3 can be estimated	(1)



Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	Method 1 (expression of K_a and) $[H^+]$ (1) - rearrangement of K_a expression & $[NH_4^+]$ (1) - number of moles of NH_4Cl (1) - mass of NH_4Cl (1) Method 2 (Use of Henderson-Hasselbalch equation) - expression of pH (1) - rearrangement of pH expression & $[NH_4^+]$ (1) - number of moles of NH_4Cl (1) - mass of NH_4Cl (1)	<u>Example of calculation</u> $(K_a = ([NH_3] \times [H^+]) \div [NH_4^+]$ and) $[H^+] = (\text{inv log } -\text{pH} =) 1.0 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$ $[NH_4^+] = ((18.1 \times 1 \times 10^{-10}) \div 5.62 \times 10^{-10} =) 3.22 \text{ (mol dm}^{-3}\text{)}$ $n(NH_4Cl) = ((3.22 \times (100 \div 1000) =) 0.322 \text{ (mol)}$ $m(NH_4Cl) = 0.322 \times 53.5 = 17.227 / 17.23 / 17.2 / 17 \text{ (g)}$ Final answer with or without working scores (4) TE at each stage Ignore SF except 1SF $\text{pH} = \text{p}K_a + \log ([NH_3] \div [NH_4^+])$ $10 = 9.25 + \log (18.1 \div [NH_4^+])$ $[NH_4^+] = (18.1 \div 10^{0.75}) = 3.22 \text{ (mol dm}^{-3}\text{)}$ $n(NH_4Cl) = ((3.22 \times (100 \div 1000) =) 0.322 \text{ (mol)}$ $m(NH_4Cl) = 0.322 \times 53.5 = 17.227 / 17.23 / 17.2 / 17 \text{ (g)}$	(4)



Question Number	Answer	Additional Guidance	Mark
7(b)(iii)	An answer that makes reference to the following point: use in fume cupboard / fume hood	Do not award use mask / well-ventilated room	(1)

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	diagram with 3 dative or covalent bonds	<u>Example of suitable diagram</u>  Allow lines for arrows Allow absence of lone pairs Do not allow dashed lines Do not award arrows going from the calcium to the N/O Do not award arrows or line coming from any other atoms to those shown Do not award double-headed arrows or curly arrows	(1)

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	3 / three		(1)

Question Number	Answer	Additional Guidance	Mark
7(d)(i)	An answer that makes reference to the following point: filter (off the precipitate)	Allow use of Buchner funnel / suction filtration / filtration under reduced pressure/ gravity filtration Ignore decant	(1)

Question Number	Answer	Additional Guidance	Mark
7(d)(ii)	Method 1 Total Hardness (M1) calculation of number of moles of EDTA^{4-} (1) (M2) calculation of number of moles of calcium ions in 1 dm^3 (1) (M3) calculation of mass of calcium ions in 1 dm^3 (1) (M4) calculation of total hardness (1) Permanent and Temporary Hardness (method as above) (M5) calculation of permanent hardness (1) (M6) calculation of temporary hardness (1)	<u>An example of calculation</u> $n(\text{EDTA}^{4-}) = ((12.80 \div 1000) \times 0.010 =) 1.28 \times 10^{-4} \text{ (mol)}$ in 50 cm^3 $n(\text{Ca}^{2+}) = n(\text{EDTA}^{4-}) = 1.28 \times 10^{-4} \text{ (mol)}$ in 1 dm^3 $n(\text{Ca}^{2+}) = 1.28 \times 10^{-4} \times 20 = 2.56 \times 10^{-3} \text{ (mol)}$ $m(\text{Ca}^{2+}) = ((2.56 \times 10^{-3} \times 40.1 = 0.102656 =) 0.10266 / 0.103 \text{ (g)}$ Total Hardness = $(0.103 \times 1000 =) 103 \text{ (mg dm}^{-3}\text{)}$ Permanent hardness $= ((5.15 \div 1000) \times 0.010 \times 20 \times 40.1 \times 1000 = 41.303)$ $= 41 \text{ (mg dm}^{-3}\text{)}$ Temporary Hardness = $(103 - 41 =) 62 \text{ (mg dm}^{-3}\text{)}$ Accept Final answer without rounding = $(102.66 - 41.30 =) 61.36 \text{ (mg dm}^{-3}\text{)}$ Final answers without working scores (6) TE at each stage Accept M1 – M4 either from the calculation of total or the permanent hardness Use of 40 for calcium gives 41.2 and 61.2 which score full marks Ignore SF except 1SF	(6)

	Method 2 • (M1) calculation of volume of EDTA⁴⁻ required for temporary hardness (1) • (M2) calculation of number of moles of EDTA⁴⁻ for permanent hardness (1) • (M3) calculation of number of moles of calcium ions in 1 dm³ for permanent hardness (1) • (M4) calculation of mass of calcium ions in 1 dm³ for permanent hardness (1) • (M5) calculation of permanent hardness (1) • (M6) calculation of temporary hardness (1)	$V = (12.80 - 5.15) = 7.65 \text{ (cm}^3\text{)}$ $n(\text{EDTA}^{4-}) = ((5.15 \div 1000) \times 0.010) = 5.15 \times 10^{-5} \text{ (mol)}$ in 50 cm³ $n(\text{Ca}^{2+}) = n(\text{EDTA}^{4-}) = 5.15 \times 10^{-5} \text{ (mol)}$ in 1 dm³ $n(\text{Ca}^{2+}) = 5.15 \times 10^{-5} \times 20 = 1.03 \times 10^{-3} \text{ (mol)}$ $m(\text{Ca}^{2+}) = ((1.03 \times 10^{-3} \times 40.1) = 0.0413 \text{ (g)})$ Permanent hardness = $(0.0413 \times 1000) = 41.3 \text{ (mg dm}^{-3}\text{)}$ Temporary hardness = $((7.65 \div 1000) \times 0.010 \times 20 \times 40.1 \times 1000) = 61.4 \text{ (mg dm}^{-3}\text{)}$ Final answers without working scores (6) TE at each stage Accept M2 – M5 either from the calculation of permanent or temporary hardness Use of 40 for calcium gives 41.2 and 61.2 which score full marks	
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(Total Question 7 = 19 marks)