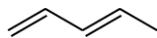




76. The compound shown below reacts with hydrogen chloride gas at room temperature and pressure to form a saturated compound.



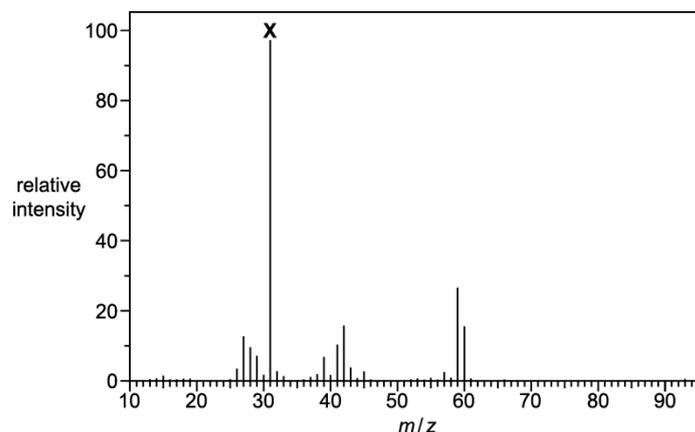
What volume of hydrogen chloride reacts with 0.25 mol of the compound?

- A 6 cm³
- B 12 cm³
- C 6 dm³
- D 12 dm³

Your answer

[1]

77(a). The mass spectrum of alcohol **A** is shown below.



Determine the structure of alcohol **A** and fragment ion **X**.

Explain your reasoning.

[3]



(b). The use of some haloalkanes, such as chlorotrifluoromethane, has been banned as they form CF_2 radicals which break down ozone.

- i. Construct an equation to show the formation of CF_2 radicals from chlorotrifluoromethane.

..... [1]

- ii. Ozone is broken down by CF_2 radicals in a two-step process.

Write the equations for the two steps and the overall equation for this process.

Step 1

.....

Step 2

.....

Overall equation

..... [3]

- iii. A research chemist found that 1.00 g of CF_2 radicals can breakdown 135 kg of O_3 .

Calculate the number of O_3 molecules removed by one CF_2 radical.

Give your answer in **standard form** and to **three** significant figures.

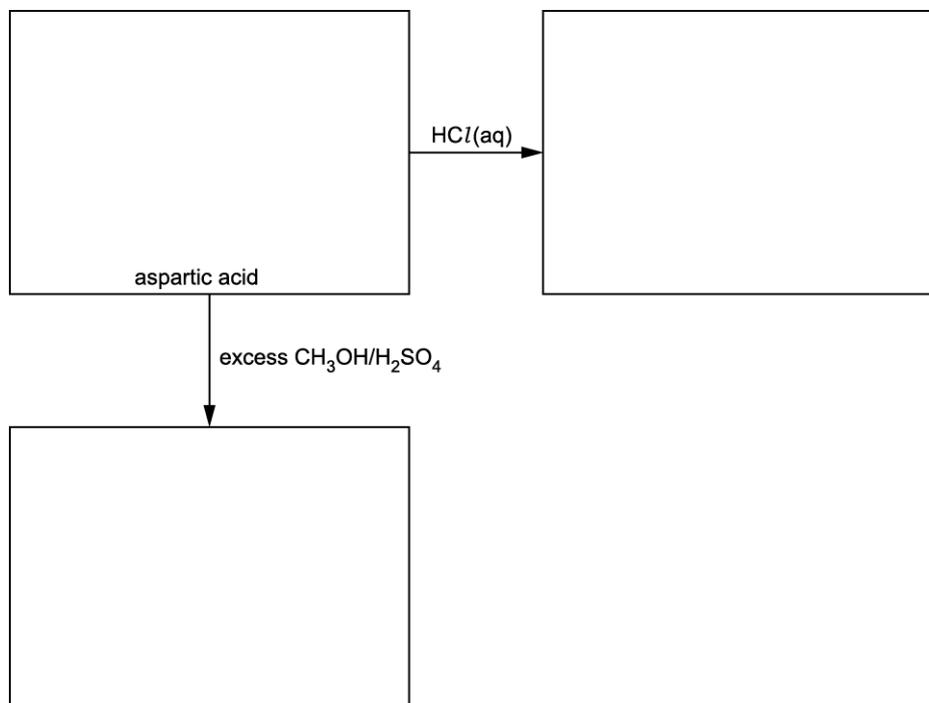
number of O_3 molecules = [3]



78. The general formula of an α -amino acid is $\text{RCH}(\text{NH}_2)\text{COOH}$.

- i. Aspartic acid ($\text{R} = \text{CH}_2\text{COOH}$) is reacted as shown in the flowchart below.

Draw the structures of aspartic acid and the missing organic products in the boxes.



[4]

- ii. Compound **G** is an α -amino acid with a **branched** R group.

0.0300 mol of **G** has a mass of 3.51 g.

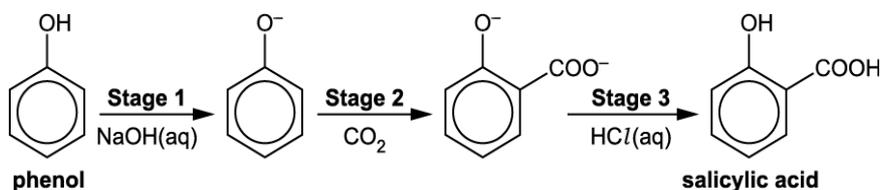
Determine the molar mass of α -amino acid **G** and suggest its structure.

[2]



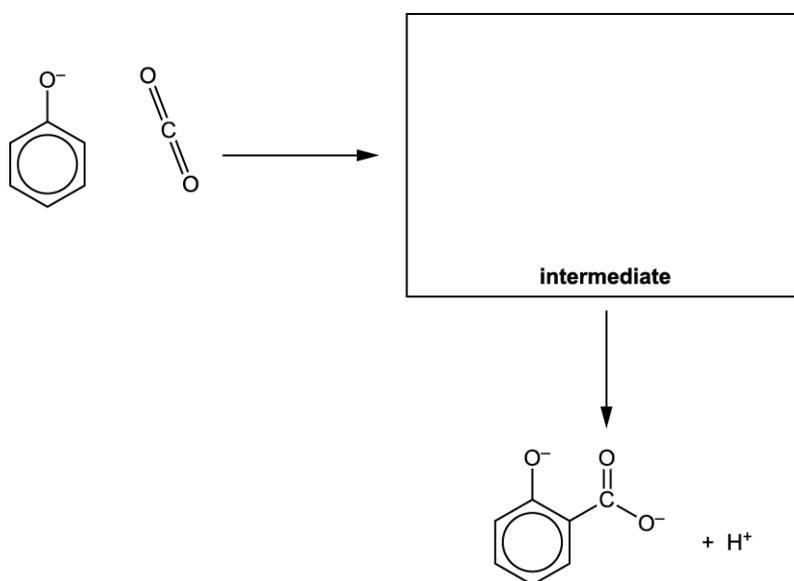
79(a). This question is about medical compounds made from salicylic acid.

Salicylic acid can be made from the reaction of phenol with carbon dioxide as shown below.



i. **Stage 2** takes place by electrophilic substitution and part of the mechanism is shown below.

Complete the mechanism by showing relevant dipoles, curly arrows and the structure of the intermediate.



[3]

ii. What type of reaction takes place during **Stage 1** and **Stage 3**?

Explain your answer.

Type of reaction

.....

Explanation

.....

.....

[2]



iii. A chemist prepares 4.83 g of salicylic acid from phenol. The percentage yield of this reaction is 45.0%.

Calculate the mass of phenol that the chemist uses.

Give your answer to **three** significant figures.

mass of phenol = g [3]

(b). Aspirin is an ester of salicylic acid.

Aspirin can be prepared by reacting salicylic acid with ethanoic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$. One other organic compound also forms.

Draw **skeletal** formulae for the products of this reaction.

[2]

80. *Compound **J** is an organic compound containing carbon, hydrogen and nitrogen only.

A chemist analyses compound **J** and the results are shown below:

Elemental analysis by mass:

C: 74.17%; H: 11.41%; N, 14.42%

Mass spectrum

Molecular ion peak at $m/z = 97.0$



81(a). This question is about chemicals used by gardeners.

A garden product contains hydrated ammonium iron(II) sulfate, $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot x\text{H}_2\text{O}$. $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot x\text{H}_2\text{O}$ contains 27.55% by mass of water of crystallisation.

Calculate the value of x in the formula $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot x\text{H}_2\text{O}$.

Show your working.

$x = \dots\dots\dots$ [3]

(b). The garden product in the previous question part is a solid mixture of the following ingredients:

- Hydrated ammonium iron(II) sulfate, $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot x\text{H}_2\text{O}$, which is soluble in water
- Crushed limestone (calcium carbonate)
- Sand.

i. Suggest why crushed limestone has been included in this garden product.

..... [1]

ii. *Plan a procedure on a test tube scale to show that the solid mixture contains the following ions:

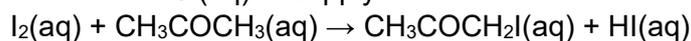
- NH_4^+ , Fe^{2+} and SO_4^{2-} present in $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot x\text{H}_2\text{O}$
- CO_3^{2-} present in crushed limestone.

Show your reasoning, including relevant equations.

..... [6]



82(a). A student investigates the rate of reaction between iodine, I_2 , and propanone, CH_3COCH_3 , in the presence of H^+ ions. The student uses $HCl(aq)$ to supply H^+ ions.



The student follows the method outlined below.

1. The student starts the reaction by mixing the following solutions.

1.00 cm³ of 1.00 mol dm⁻³ $I_2(aq)$

49.5 cm³ of 1.00 mol dm⁻³ $CH_3COCH_3(aq)$

49.5 cm³ of 1.00 mol dm⁻³ $HCl(aq)$

2. The student places a sample of the reaction mixture in a colorimeter, immediately starts a stopwatch, and records the absorbance.

3. The student records the absorbance every 100 s. The results are shown below.

Time/s	Absorbance
0	0.80
100	0.67
200	0.51
300	0.44
400	0.28
500	0.18
600	0.05

Explain why absorbance decreases during the experiment.

[1]

(b). Absorbance is proportional to the concentration of I_2 .

Calculate the concentration of I_2 at the start of the experiment and after 500 s.

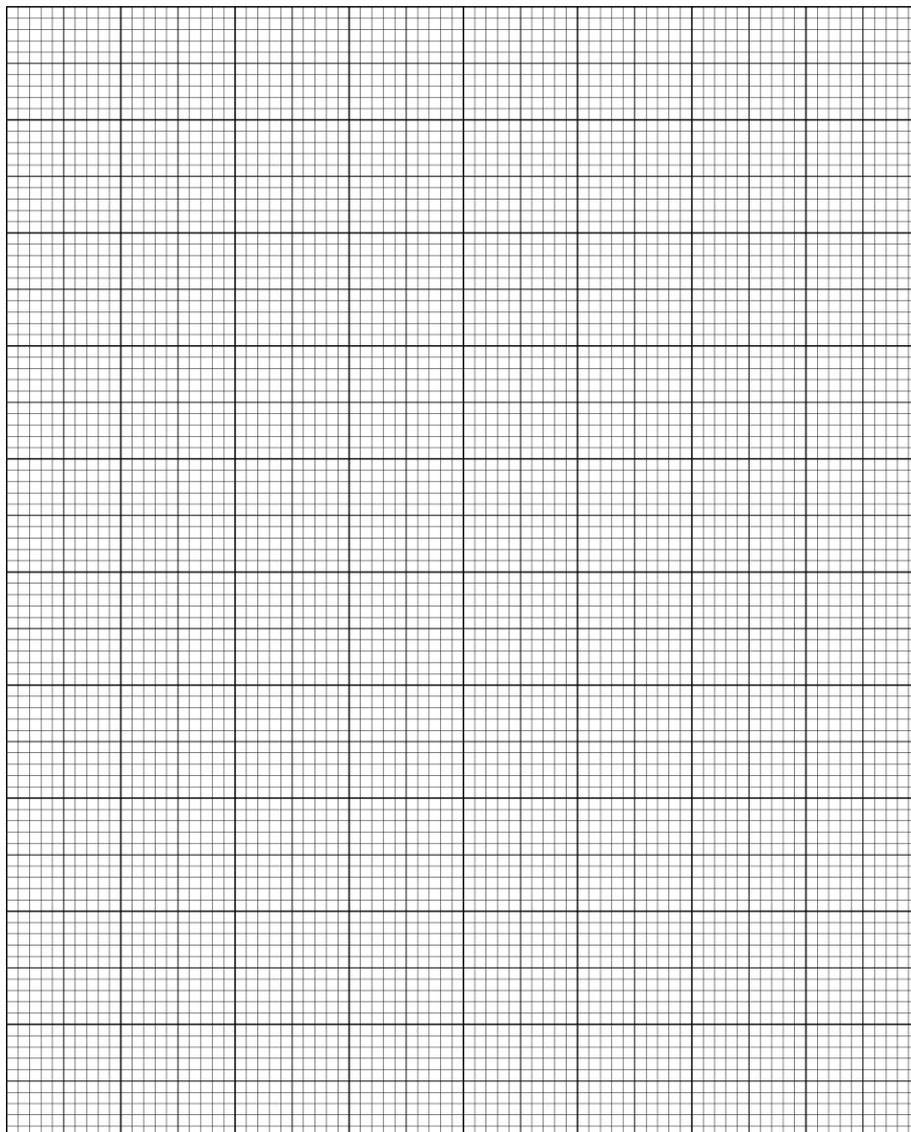
Time/s	Absorbance	$[I_2(aq)]/\text{mol dm}^{-3}$
0	0.80	
500	0.18	

[2]



(c).

- i. Plot a graph of absorbance against time and draw a line of best fit.



[3]

- ii. Use your graph to find the order of reaction with respect to iodine.

Explain your reasoning.

Order

.....

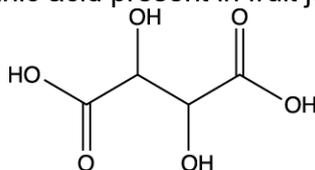
Explanation

.....

[2]



(b). Tartaric acid, shown below, is an organic acid present in fruit juice.



i. What is the empirical formula of tartaric acid?

..... [1]

ii. Write the systematic name for tartaric acid.

..... [1]

iii. Tartaric acid reacts with 1,6-diaminohexane, $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$, to form a polymer.

Draw the structure of **one** repeat unit of this polymer.

[2]

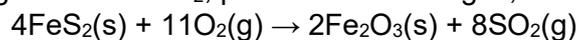
iv. The polymerisation in (iii) takes place in two steps.

In the first step, tartaric acid and 1,6-diaminohexane react to form a salt.

Draw the structure of this salt, showing the ions present.

[2]

84. Combustion of coal, containing traces of FeS_2 , produces the acid gas, sulfur dioxide, SO_2 .



A batch of coal contains 3.00% by mass of FeS_2 .

Calculate the volume of SO_2 gas, in m^3 , produced by combustion of 1.00 tonne of this coal at 50.0°C and a pressure of 100 kPa.

Give your answer to an **appropriate** number of significant figures.

volume = m^3 [5]



85. 0.0200 mol of calcium oxide is reacted completely with $2.00 \text{ mol dm}^{-3} \text{ HCl}$.
What is the volume, in cm^3 , of $2.00 \text{ mol dm}^{-3} \text{ HCl}$ required for this reaction?

- A 15
- B 20
- C 30
- D 60

Your answer

[1]

86. How many electrons are removed from $2.02 \times 10^{-2} \text{ g}$ of Ne(g) atoms to form $\text{Ne}^+(\text{g})$ ions?

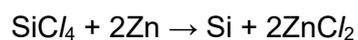
- A 3.36×10^{-26}
- B 1.66×10^{-27}
- C 6.02×10^{20}
- D 1.22×10^{22}

Your answer

[1]



87. Silicon can be made by heating silicon tetrachloride, SiCl_4 , with zinc.



8.50 g of SiCl_4 is reacted with an excess of zinc. The percentage yield of silicon is 90%.

What is the mass of silicon made?

- A 1.26 g
- B 1.31 g
- C 1.40 g
- D 1.55 g

Your answer

[1]

88. **HA** and **HB** are two strong monobasic acids.

25.0 cm^3 of 6.0 mol dm^{-3} **HA** is mixed with 45.0 cm^3 of 3.0 mol dm^{-3} **HB**.

What is the $\text{H}^+(\text{aq})$ concentration, in mol dm^{-3} , in the resulting solution?

- A 1.9
- B 2.1
- C 4.1
- D 4.5

Your answer

[1]



89. Complete combustion of an organic compound forms 40 cm^3 of carbon dioxide and 40 cm^3 of water vapour, under the same conditions of temperature and pressure.

Which molecular formula could the organic compound have?

- A** C_3H_8
- B** $\text{C}_2\text{H}_2\text{O}$
- C** $\text{C}_2\text{H}_4\text{O}$
- D** $\text{C}_2\text{H}_3\text{N}$

Your answer

[1]

90. Which type of reaction has the greatest atom economy?

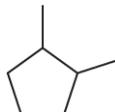
- A** Substitution
- B** Hydrolysis
- C** Elimination
- D** Addition

Your answer

[1]



91. What is the molecular formula of the compound below?



- A C_7H_{10}
- B C_7H_{12}
- C C_7H_{14}
- D C_7H_{16}

Your answer

[1]

92. 0.1 mol of $\text{HOOCCH}_2\text{COOH}$ are reacted with 0.1 mol of aqueous NaOH .

How many molecules of water are formed?

- A 6.02×10^{22}
- B 3.01×10^{22}
- C 6.02×10^{23}
- D 3.01×10^{23}

Your answer

[1]



94. An organic compound has the composition by mass:

C, 53.33 %; H, 11.11%; O, 35.56%.

What is the empirical formula of the organic compound?

- A $C_4H_8O_2$
- B $C_4H_{10}O_2$
- C C_2H_4O
- D C_2H_5O

Your answer

[1]

95. Samples of four hydrocarbons are completely burnt under the same conditions of temperature and pressure.

Which sample produces the greatest volume of CO_2 ?

- A 0.4 mol C_2H_6
- B 0.3 mol C_3H_8
- C 0.2 mol C_4H_{10}
- D 0.1 mol C_5H_{12}

Your answer

[1]



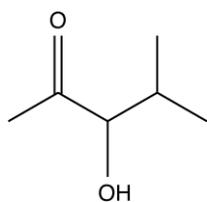
96. Which reaction produces the smallest atom economy of BaCl_2 ?

- A $\text{BaCl}_2 \cdot 2\text{H}_2\text{O} \rightarrow \text{BaCl}_2 + 2\text{H}_2\text{O}$
- B $\text{BaO} + 2\text{HCl} \rightarrow \text{BaCl}_2 + \text{H}_2\text{O}$
- C $\text{BaCO}_3 + 2\text{HCl} \rightarrow \text{BaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$
- D $\text{Ba} + 2\text{HCl} \rightarrow \text{BaCl}_2 + \text{H}_2$

Your answer

[1]

97. The skeletal formula of an organic compound is shown below.



What is the molecular formula of the organic compound?

- A $\text{C}_6\text{H}_{10}\text{O}_2$
- B $\text{C}_6\text{H}_{11}\text{O}_2$
- C $\text{C}_6\text{H}_{12}\text{O}_2$
- D $\text{C}_6\text{H}_{13}\text{O}_2$

Your answer

[1]

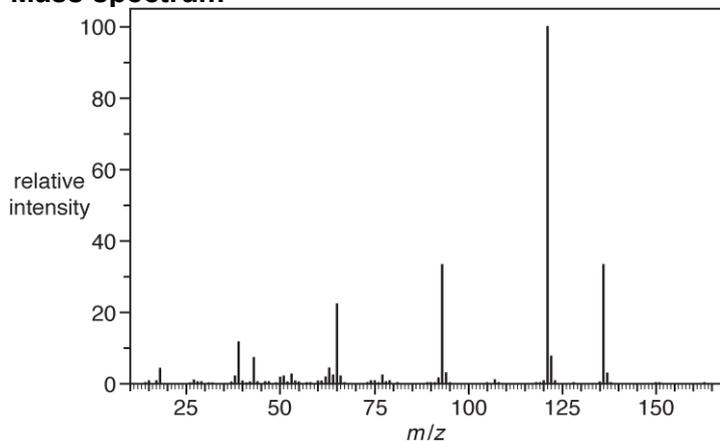


98(a). A chemist analyses a naturally occurring aromatic compound.

The percentage composition and mass spectrum of the compound are shown below.

Percentage composition by mass: C, 70.58%; H, 5.92%; O, 23.50%.

Mass spectrum



Determine the molecular formula of the compound.
Show your working.

molecular formula = [3]

(b). Qualitative tests are carried out on the aromatic compound. The results are shown below.

Test	Acidity	$\text{Na}_2\text{CO}_3(\text{aq})$	2,4-DNP	Tollens' reagent
Observation	pH = 5	No observable change	Orange precipitate	No observable change

Determine the functional groups in the compound. Explain your reasoning.

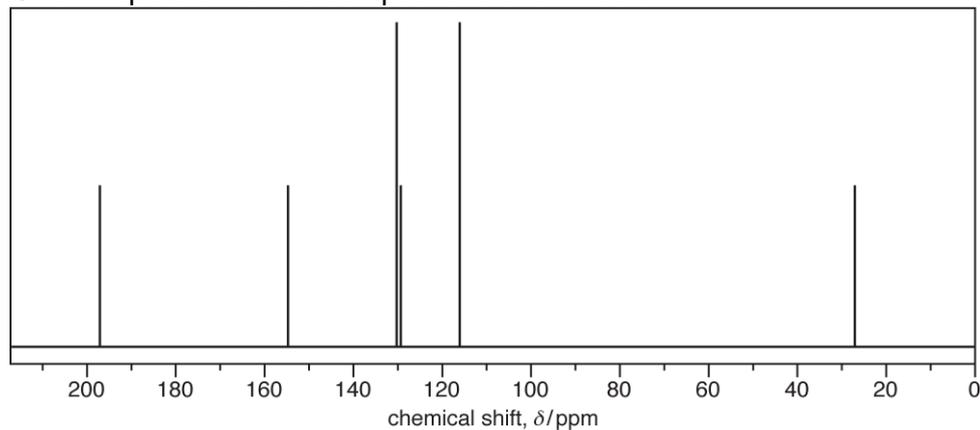
Functional groups

Explanation

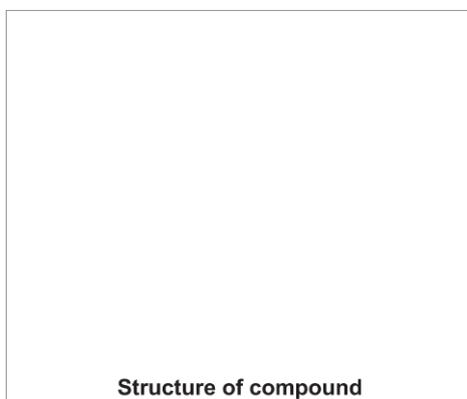
..... [3]



(c). The carbon-13 NMR spectrum of the compound is shown below.



Using the spectrum and the results from (a) and (b), determine the structure of the compound. Explain your reasoning.



[3]



- i. Outline the mechanism for this nitration of benzoic acid.

Show how H_2SO_4 behaves as a catalyst.

[5]

- ii.  A chemist carries out the reaction in **Equation 17.1** using 4.97 g of benzoic acid.

The chemist obtains 3-nitrobenzoic acid as an impure solid.

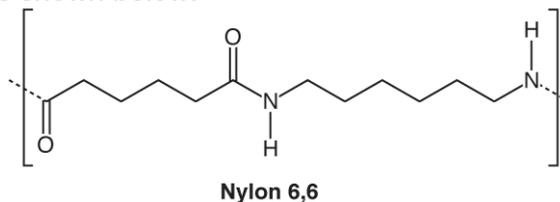
The chemist purifies the solid to obtain 4.85 g of 3-nitrobenzoic acid.

Describe a method to obtain a pure sample of 3-nitrobenzoic acid from the impure solid, determine the percentage yield and check its purity.



[6]

101. The repeat unit of Nylon 6,6 is shown below.



i. Draw the structures of **two** monomers that can be used to form Nylon 6,6.

[2]

ii. A sample of Nylon 6,6 has a relative molecular mass of 21500.
Estimate the number of repeat units in the sample.
Give your answer as a **whole** number.

number of repeat units = [1]



102(a). Within the permafrost in Arctic regions of the Earth, large amounts of methane are trapped within ice as 'methane hydrate', $\text{CH}_4 \cdot x\text{H}_2\text{O}$. Methane makes up about 13.4% of the mass of 'methane hydrate'.

Scientists are concerned that global warming will melt the permafrost, releasing large quantities of methane into the atmosphere.

Determine the formula of 'methane hydrate', $\text{CH}_4 \cdot x\text{H}_2\text{O}$.

In the formula, show the value of x to **two** decimal places.

formula = _____ [2]

(b). Calculate the volume of methane, in dm^3 , that would be released from the melting of each 1.00 kg of 'methane hydrate' at 101 kPa and 0°C .

Give your answer to **three** significant figures.

volume = _____ dm^3 [4]



103(a). A student plans to determine the enthalpy change of **reaction 3.1** shown below.



This enthalpy change can be determined indirectly using Hess' Law from the enthalpy changes of **reaction 3.2** and **reaction 3.3** shown below.



The student will determine the enthalpy change of **reaction 3.2** as outlined below.

- Weigh a bottle containing $\text{Na}_2\text{O}(\text{s})$ and weigh a polystyrene cup.
- Add about 25 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $\text{Na}_2\text{O}(\text{s})$, stir the mixture, and measure the maximum temperature reached.
- Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

Mass of bottle + $\text{Na}_2\text{O}(\text{s})$	= 16.58 g
Mass of empty bottle	= 15.34 g
Mass of empty polystyrene cup	= 21.58 g
Mass of polystyrene cup + final solution	= 47.33 g

Temperature readings

Initial temperature of water	= $20.5 \text{ }^\circ\text{C}$
Maximum temperature of final solution	= $55.5 \text{ }^\circ\text{C}$

The density and specific heat capacity, c , of the solution are the same as for water.



Calculate the enthalpy change of **reaction 3.2** and the enthalpy change of **reaction 3.1**.

Show all your working.

[6]

(b). The uncertainty in each temperature reading is ± 0.1 °C.

The uncertainty in each mass reading is ± 0.005 g.

Determine whether the mass of Na_2O or the temperature change has the greater percentage uncertainty.

Show all your working.

[2]

(c). Suggest a modification to this experiment, using the **same** apparatus, which would reduce the percentage errors in the measurements.

Explain your reasoning.



[2]

104(a). This question is about weak acids.

Compound **A** is a weak monobasic acid.

A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of **A**.

The student titrates 25.0 cm^3 samples of this solution with $0.0840 \text{ mol dm}^{-3}$ NaOH in the burette.

The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three **further** titrations.

All burette readings are measured to the nearest 0.05 cm^3 .

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading

i. Record the student's readings and the titres in an appropriate format.

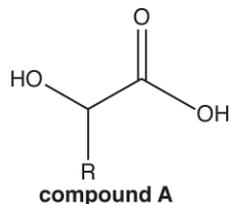
Calculate the mean titre that the student should use for analysing the results.

mean titre = _____ cm^3 [4]

ii.



iii. The structure of compound **A** is shown below.



Compound **A** has four optical isomers.

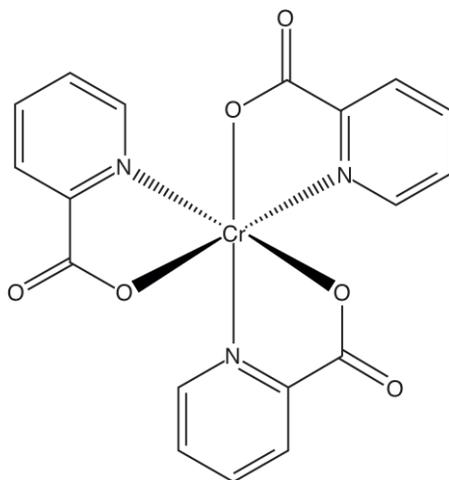
Using this information and the student's results, answer the following.

- Determine the molar mass of **A** and the formula of the alkyl group R.
- Draw the structure of compound **A** and label any chiral carbon atoms with an asterisk*.

Show all your working.



(b). Chromium (III) picolinate, shown below, is a neutral complex that can be prepared from the weak acid, picolinic acid.



Chromium(III) picolinate is used in tablets as a nutritional supplement for chromium.

i. Draw the structure of the ligand in chromium(III) picolinate.

[1]

ii. A typical tablet of chromium(III) picolinate contains 200 μg of chromium.

Calculate the mass, in g, of chromium (III) picolinate in a typical tablet.

$1 \mu\text{g} = 10^{-6} \text{g}$.

Give your answer to **three** significant figures.

mass =

g [2]



105(a). Barium combines with oxygen, chlorine and nitrogen to form ionic compounds.

Barium oxide, BaO, has a giant ionic lattice structure.

- i. State what is meant by the term *ionic bond*.

[1]

- ii. Draw a '*dot-and-cross*' diagram to show the bonding in barium oxide.

Show outer electrons only.

[2]

- iii. Calculate the number of barium ions in 1.50 g of barium oxide.

Give your answer in standard form and to **three** significant figures.

number of barium ions = [2]



(b). Barium chloride, BaCl_2 , is soluble in water.

i. Compare the electrical conductivities of solid and aqueous barium chloride.

Explain your answer in terms of the particles involved.

[2]

ii. Describe the use of aqueous barium chloride in qualitative analysis.

[2]

iii. Hydrated barium chloride can be crystallised from solution.

Hydrated barium chloride has the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$ and a molar mass of 244.3 g mol^{-1} .

Determine the value of x in the formula of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

Show your working.

$x = \dots\dots\dots$ [2]

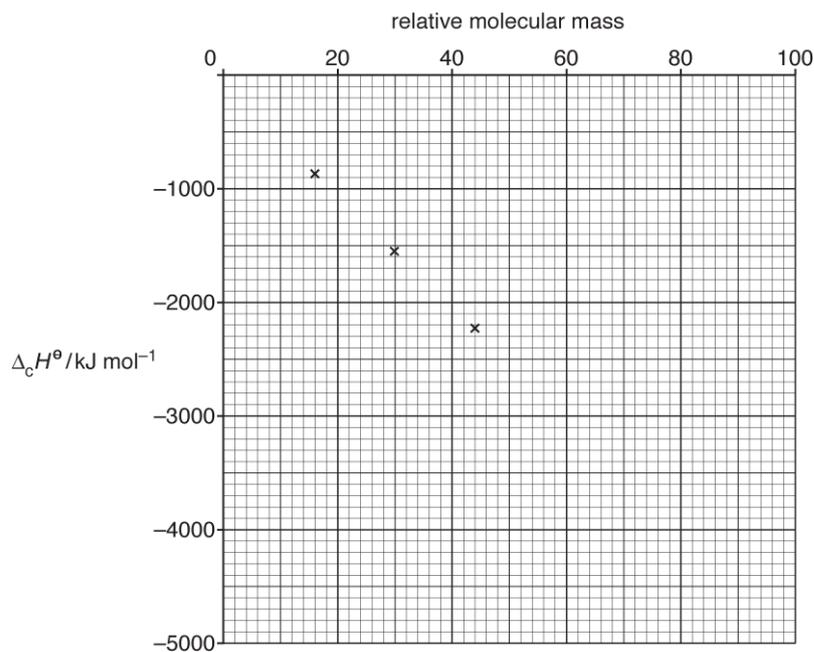


106. Data book values for the standard enthalpy changes of combustion, $\Delta_c H^\theta$, of the first four alkanes are shown in the table.

Alkane	methane	ethane	propane	butane
$\Delta_c H^\theta / \text{kJ mol}^{-1}$	-890	-1560	-2219	-2877

i. The values for the first three alkanes are plotted on the graph below.

Plot the value for butane on the graph.



[1]

ii. Use the graph to estimate the energy released during complete combustion of 1.80 g of pentane.

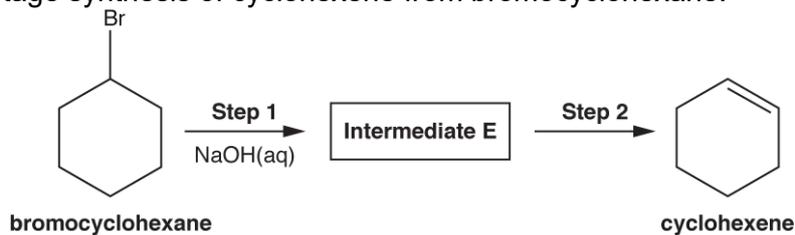
Show relevant working below and on the graph.

energy released = kJ [3]



107. Organic compounds can be prepared in the laboratory using synthetic routes with two or more stages.

A student devises a two-stage synthesis of cyclohexene from bromocyclohexane.



- i. Suggest the structure of **intermediate E** and the reagent(s) and conditions for **step 2**.

reagent(s) and conditions

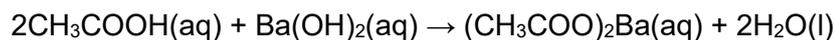
[2]

- ii. The student carries out this synthesis and obtains 1.23 g of pure cyclohexene from 5.50 g of bromocyclohexane.

Calculate the percentage yield of cyclohexene.

Give your final answer to an **appropriate** number of significant figures.

percentage yield = % [3]



- i. Calculate the concentration, in mol dm^{-3} , of CH_3COOH in the original bottle of vinegar. Show your working.

concentration of CH_3COOH = mol dm^{-3} [4]

- ii. Suggest **one** assumption that the student has made that might mean that their calculated concentration of ethanoic acid in the vinegar is invalid. Predict, with a reason, how the experimental result would differ from the actual concentration of CH_3COOH if the assumption were **not** correct.

..... [2]

110. An alkene **D** is a liquid at room temperature and pressure but can easily be vaporised.

When vaporised, 0.1881 g of **D** produces 82.5 cm^3 of gas at 101 kPa and 373 K.

Determine the molar mass and molecular formula of alkene **D**.

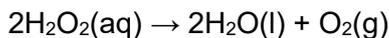
Show all your working.

molar mass = g mol^{-1}

molecular formula = [5]



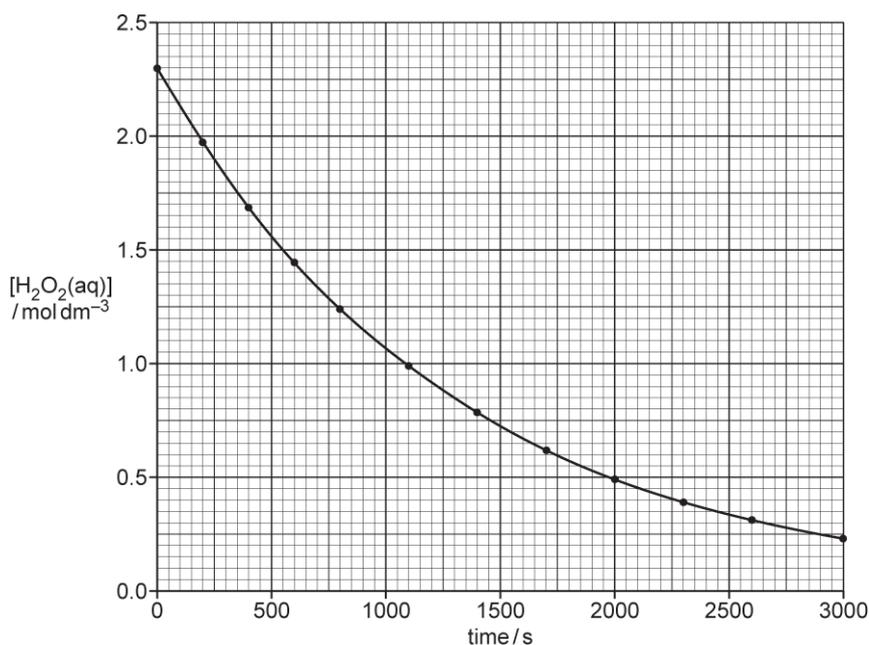
111(a). Aqueous solutions of hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$, decompose as in the equation below.



A student investigates the decomposition of $\text{H}_2\text{O}_2(\text{aq})$ by measuring the volume of oxygen gas produced over time. All gas volumes are measured at room temperature and pressure.

The student uses 25.0 cm^3 of 2.30 mol dm^{-3} H_2O_2 .

From the results, the student determines the concentration of $\text{H}_2\text{O}_2(\text{aq})$ at each time. The student then plots a concentration–time graph.



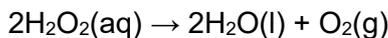
Determine the total volume of oxygen, measured at room temperature and pressure, that the student should be prepared to collect in this investigation.

Suggest apparatus that would allow this gas volume to be collected, indicating clearly the scale of working.



[3]

(b). Aqueous solutions of hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$, decompose as in the equation below.



A student investigates the decomposition of $\text{H}_2\text{O}_2(\text{aq})$ by measuring the volume of oxygen gas produced over time. All gas volumes are measured at room temperature and pressure.

The student uses 25.0 cm^3 of 2.30 mol dm^{-3} H_2O_2 .

From the results, the student determines the concentration of $\text{H}_2\text{O}_2(\text{aq})$ at each time. The student then plots a concentration–time graph.

Suggest a different experimental method that would allow the rate of this reaction to be followed over time.

[1]

112. This question is about the properties and reactions of ethanoic acid, CH_3COOH .

Ethanoic acid is a weak acid with an acid dissociation constant, K_a , of $1.75 \times 10^{-5} \text{ mol dm}^{-3}$ at $25 \text{ }^\circ\text{C}$.

The student plans to prepare a buffer solution that has a pH of 4.50. The buffer solution will contain ethanoic acid, CH_3COOH , and sodium ethanoate, CH_3COONa .

The student plans to add 9.08 g CH_3COONa to 250 cm^3 of $0.800 \text{ mol dm}^{-3}$ CH_3COOH . The student assumes that the volume of the solution does not change.

- i. Show by calculation whether, or not, the student's experimental method would produce the required pH.

Show **all** your working.

[5]



- ii. When the student prepares the buffer solution, the volume of solution increases slightly.

Suggest whether the pH of the buffer solution would be the same, greater than, or less than your calculated value in (c)(i).

Explain your reasoning.

[2]

113.  A hydrated nickel(II) complex, **A**, is heated in a crucible to remove the water of crystallisation. The anhydrous complex **B** is formed. The results are shown below.

Mass of crucible + hydrated complex A	= 59.554 g
Mass of crucible + anhydrous complex B	= 58.690 g
Mass of crucible	= 51.257 g

The anhydrous complex **B** is analysed and found to have a molar mass of 309.7 g mol^{-1} and to contain the following percentage composition by mass:

Ni, 18.95%; C, 23.25%; N, 27.12%; H, 7.75%; Cl, 22.93%.

The anhydrous complex **B** contains a cation **C** comprising Ni, C, N and H only.

Cation **C** is six-coordinate, contains three molecules of the bidentate ligand **D**, and exists as optical isomers.

Determine the formula of **A**, **B**, **C** and **D** and show the 3D structures for the optical isomers of **C**.

Show **all** your working.



[6]

114. Bromine is a reactive element. It combines with other non-metals to form covalent compounds. Phosphorus tribromide, PBr_3 , and iodine monobromide, IBr , are examples of covalent compounds used in organic synthesis.

PBr_3 can be prepared by heating bromine with phosphorus, P_4 .

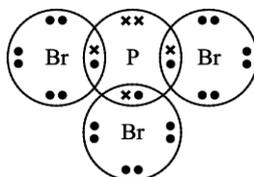
- i. Write an equation for this reaction.

[1]

- ii. How many molecules are present in 1.3535 g of PBr_3 ?

number of molecules = [3]

- iii. The 'dot-and-cross' diagram of a molecule of PBr_3 is given below.



Name the shape of this molecule and explain why the molecule has this shape.

name:

explanation:

[3]



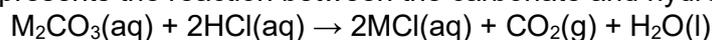
- i. Record the student's readings and the titre.

[1]

- ii. Describe what the student should do next to obtain reliable results for the titration.

[1]

- (b). The equation below represents the reaction between the carbonate and hydrochloric acid.



- i. Calculate the amount, in mol, of M_2CO_3 used in the titration.

$$n(\text{M}_2\text{CO}_3) = \dots\dots\dots\text{mol} \quad [2]$$

- ii. The student's mass readings are recorded below.

Mass of weighing bottle + carbonate / g	14.92
Mass of weighing bottle / g	13.34

Use the student's results to identify the carbonate, M_2CO_3 .

Show **all** your working.

[4]



118(a). A student carries out a titration to determine the molar mass and structure of a weak acid **A**.

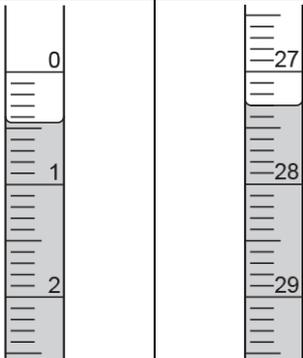
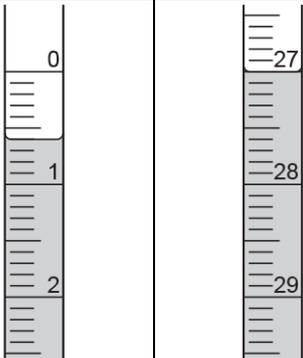
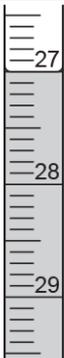
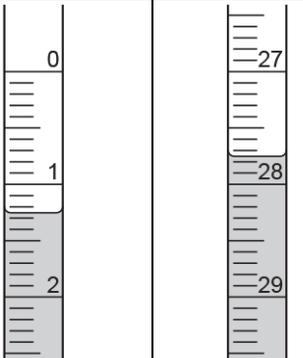
The student follows the method below.

- Dissolve a weighed mass of **A** in 100 cm³ of distilled water and make the solution up to 250 cm³ in a beaker.
- Add the solution of **A** to a burette.
- Titrate the solution of **A** with a standard solution of sodium hydroxide, NaOH.

The student carries out a trial, followed by three further titrations.

The diagram shows the initial and final burette readings for the three **further** titrations.

The student measures all burette readings to the nearest 0.05 cm³.

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

i. Record the student's readings and the titres in the table below.

Calculate the mean titre, to the nearest 0.05 cm³, that the student should use for analysing the results.

	Titration 1	Titration 2	Titration 3
Final reading/cm ³			
Initial reading/cm ³			
Titre/cm ³			

mean titre = _____

cm³ [4]



- ii. The uncertainty in each burette reading is $\pm 0.05 \text{ cm}^3$.

Calculate the percentage uncertainty for the titre in **Titration 1**.

percentage uncertainty = _____ % [1]

- iii. The student realised that the solution of **A** had not been prepared correctly.

How should the student have made up the solution?

----- [1]

(b). A student repeats the titration to determine the molar mass and structure of **A**.

- The student prepares a 250.0 cm^3 solution from 1.513 g of **A**.
- The solution of **A** is added to the burette and titrated with 25.0 cm^3 volumes of $0.112 \text{ mol dm}^{-3}$ NaOH(aq) .
- 1 mol of **A** reacts with 2 mol of NaOH .
- The student obtains a mean titre of 27.30 cm^3 .

- i. Calculate the molar mass of **A** from these results.

Give your answer to the nearest whole number.

Show your working.

molar mass of **A** = _____ g mol^{-1} [4]



- ii. **A** is an organic acid, containing C, H and O only.
One molecule of **A** contains two COOH groups.

Suggest the structure of **A**.

[1]

119. Selenium is in the same group of the periodic table as sulfur.

- i. Complete the full electron configuration of a selenium atom.

1s²

[1]

- ii. Sodium selenide reacts with hydrochloric acid to form a toxic gas, **B**, with a relative molecular mass of 81.0.

Identify gas **B** and write an equation for this reaction.

Gas B

Equation

[2]

120. The reaction of ammonia, NH₃, with oxygen to form nitrogen monoxide, NO, is an important industrial process.

The equation for this reaction is shown in **equilibrium 4.1** below.

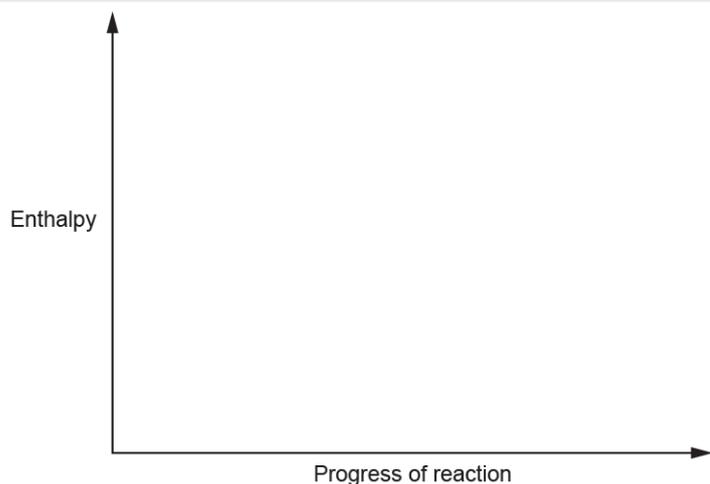


The forward reaction in **equilibrium 4.1** converts NH₃ into NO.

- i. Complete the enthalpy profile diagram for this reaction.

On your diagram:

- Label the activation energy, E_a
- Label the enthalpy change of reaction, ΔH
- Include the formulae of the reactants and products.



[2]

- ii. 5.10 tonnes of NH_3 are converted into NO.

Calculate the energy released, in kJ, for this conversion.

Give your answer in **standard form** and to an **appropriate** number of significant figures.

energy released =

kJ [4]

121(a).

1-Bromobutane is an organic liquid with a boiling point of $102\text{ }^\circ\text{C}$.

A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour.

The equation is shown below.



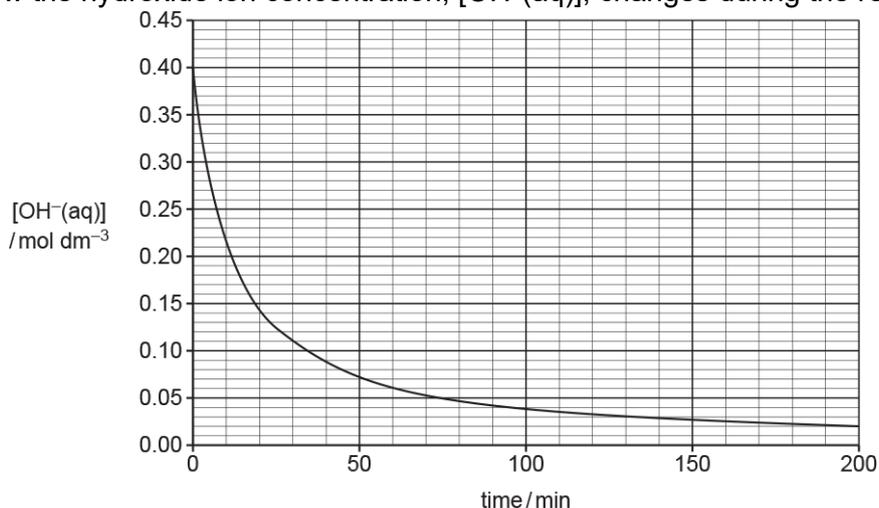
The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm^{-3}) and an aqueous layer (density = 1.00 g cm^{-3}).

- i. * Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.



(b). A student investigates the rate of reaction of 1-bromobutane with aqueous hydroxide ions.

The graph shows how the hydroxide ion concentration, $[\text{OH}^-(\text{aq})]$, changes during the reaction.



Using the graph, calculate the rate of reaction, in $\text{mol dm}^{-3} \text{min}^{-1}$, at 30 minutes.

Show your working on the graph and in the space below.

rate of reaction = _____ $\text{mol dm}^{-3} \text{min}^{-1}$ [2]

122. What is the number of hydrogen atoms in 0.125 mol of $\text{C}_2\text{H}_5\text{OH}$?

- A 7.525×10^{22}
- B 4.515×10^{23}
- C 3.7625×10^{23}
- D 3.612×10^{24}

Your answer

[1]



123. A student titrates a standard solution of barium hydroxide, $\text{Ba}(\text{OH})_2$, with nitric acid, HNO_3 .

25.00 cm^3 of $0.0450 \text{ mol dm}^{-3}$ $\text{Ba}(\text{OH})_2$ are needed to neutralise 23.35 cm^3 of $\text{HNO}_3(\text{aq})$.

What is the concentration, in mol dm^{-3} , of the nitric acid?

- A** 0.0241
- B** 0.0482
- C** 0.0900
- D** 0.0964

Your answer

[1]

124. Many solid drain cleaners are based on sodium hydroxide, NaOH .

- A student dissolves 1.26 g of a drain cleaner in water and makes up the solution to 100.0 cm^3 .
- The student measures the pH of this solution as 13.48.

Determine the percentage, by mass, of NaOH in the drain cleaner.

Give your answer to **three** significant figures.

percentage = % [4]



125(a). Compound **A** is an oxide of chlorine that is a liquid at room temperature and pressure and has a boiling point of 83 °C.

When 0.4485 g of **A** is heated to 100 °C at 1.00×10^5 Pa, 76.0 cm³ of gas is produced.

Determine the molecular formula of compound **A**.

Show all your working.

molecular formula of **A** = [4]

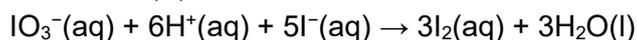
(b). Compound **B** is an iodate(V) salt of a Group 1 metal.
The iodate(V) ion has the formula IO₃⁻.

A student carries out a titration to find the formula of compound **B**.

Step 1: The student dissolves 1.55 g of **B** in water and makes up the solution to 250.0 cm³ in a volumetric flask.

Step 2: The student pipettes 25.00 cm³ of the solution of **B** into a conical flask, followed by 10 cm³ of dilute sulfuric acid and an excess of KI(aq).

The iodate(V) ions are reduced to iodine, as shown below.



Step 3: The resulting mixture is titrated with 0.150 mol dm⁻³ Na₂S₂O₃(aq).
 $2\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{aq}) \rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + 2\text{I}^-(\text{aq})$

The student repeats **step 2** and **step 3** until concordant titres are obtained.





Titration readings

Titration	Trial	1	2	3
Final burette reading / cm ³	24.00	47.40	23.75	47.05
Initial burette reading / cm ³	0.00	24.00	0.00	23.20
Titre / cm ³				

Table 20.1

- i. Complete **Table 20.1** and calculate the mean titre that the student should use for analysing the results.

mean titre = cm³ [2]

- ii. The uncertainty in each burette reading is ± 0.05 cm³.

Calculate the percentage uncertainty in the titre obtained from **titration 1**.

Give your answer to **two** decimal places.

percentage uncertainty = % [1]

- iii. Describe and explain how the student should determine the end point of this titration accurately.

[2]

- iv. Determine the relative formula mass and formula of the Group 1 iodate(V), **B**.

Show your working.



relative formula mass of **B** =

formula of **B** = [5]

126. * Three different reactions of copper compounds are described below.

Reaction 1: Aqueous copper(II) sulfate reacts with excess aqueous ammonia in a ligand substitution reaction. A deep-blue solution is formed, containing an octahedral complex ion, **C**, which is a trans isomer.

Reaction 2: Copper(I) oxide reacts with hot dilute sulfuric acid in a disproportionation reaction. A blue solution, **D**, and a brown solid, **E** are formed.

Reaction 3: Copper(II) oxide reacts with warm dilute nitric acid in a neutralisation reaction, to form a blue solution. Unreacted copper(II) oxide is filtered off, and the solution is left overnight in an evaporating basin.
A hydrated salt, **F**, crystallises, with the percentage composition by mass:
Cu, 26.29%; H, 2.48%; N, 11.59%; O, 59.63%.

Identify **C–F** by formulae or structures, as appropriate.

Include equations, any changes in oxidation number, and working.

[6]



127. Ethanol can be prepared by different reactions.

Which reaction has the lowest atom economy?

- A** $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$
B $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$
C $\text{C}_2\text{H}_5\text{Br} + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH} + \text{HBr}$
D $\text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH} + \text{CH}_3\text{COOH}$

Your answer

[1]



128. A student hydrolyses a haloalkane, **E**, using the following method.

- 0.0100 mol of haloalkane **E** is refluxed with excess NaOH(aq) to form a reaction mixture containing an organic product **F**.
- The reaction mixture is neutralised with dilute nitric acid.
- Excess AgNO₃(aq) is added to the reaction mixture. 1.88 g of a precipitate **G** forms.

Organic product, **F**, has a molar mass of 74.0 g mol⁻¹ and has a chiral carbon atom.

- i. Draw a **labelled** diagram to show how the student would carry out the hydrolysis of haloalkane **E**.

[2]

- ii. Analyse the information to identify **E**, **F** and **G**.

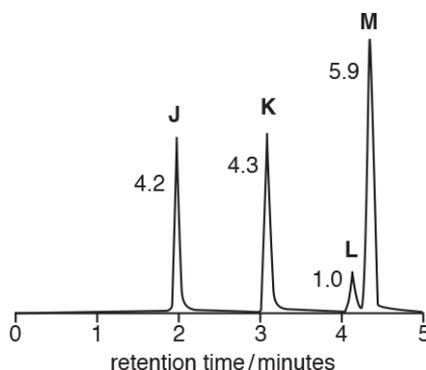
Show your working.

[3]



129. A cosmetic product containing four esters, **J**, **K**, **L** and **M**, is analysed by gas chromatography and mass spectrometry. The results are shown below.

Gas chromatogram



The numbers by the peaks are the relative molar proportions of the compounds in the mixture.

Mass spectrometry

ester	<i>m/z</i> of molecular ion peak
J	152
K	166
L	180
M	180

- i. The concentration of ester **K** in the cosmetic product is $9.13 \times 10^{-2} \text{ g dm}^{-3}$.

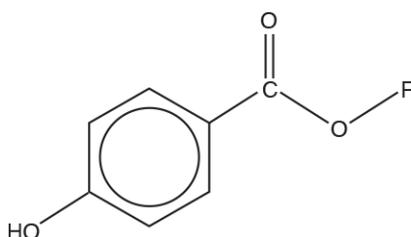
Using the results, calculate the concentration, in mol dm^{-3} , of ester **M** in the cosmetic product.

Give your answer to **two** significant figures.

concentration of ester **M** =

mol dm^{-3} [2]

- ii. A general structure for esters **J**, **L** and **M** is shown below.





Where 'R' is an alkyl group.

Use the mass spectrometry results to deduce possible structures for esters **J**, **L** and **M**.

J	L	M
----------	----------	----------

[3]

130(a). Fuel additives are often used to improve the combustion of a fuel.

i. Compound **N** is a fuel additive containing carbon, hydrogen and oxygen only.

Complete combustion of 1.71 g of compound **N** produces 2.97 g of CO_2 and 1.62 g of H_2O . The relative molecular mass of compound **N** is 76.0.

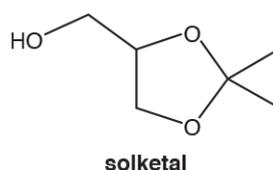
Calculate the molecular formula of **N** and suggest a possible structure for the compound.

compound N

[5]



ii. Solketal has been investigated as a potential fuel additive.



Solketal is synthesised from propane-1,2,3-triol and a carbonyl compound.

Construct a balanced equation for this synthesis.

Show structures for the organic compounds in your equation.

[2]

(b). A scientist is researching compounds that might be suitable as fuel additives. One of the compounds gives the analytical results below.

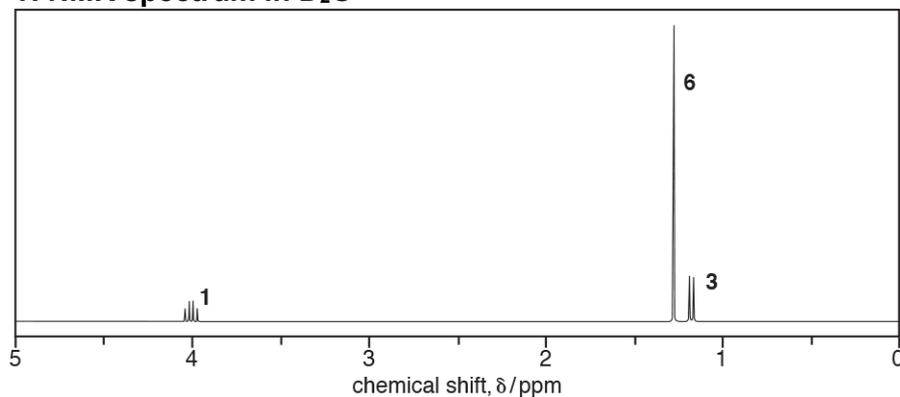
Elemental analysis by mass:

C: 54.54%; H: 9.10%; O: 36.36%

Mass spectrum:

Molecular ion peak at $m/z = 132.0$

^1H NMR spectrum in D_2O



The numbers by the peaks are the relative peak areas.

When the spectrum is run without D_2O , there are **two** additional peaks with the same relative peak areas at 11.0 ppm and 3.6 ppm.

Use the information provided to suggest a structure for the compound.

Show all your reasoning.

[6]



131. This question refers to the elements in the first three periods (H → Ar) of the Periodic Table.

Select an element from the first three periods that fits each of the following descriptions.

- i. The element that forms a 1- ion with the same electron configuration as helium.

_____ [1]

- ii. The element with the highest first ionisation energy.

_____ [1]

- iii. The element in Period 3 which has the successive ionisation energies shown below.



Ionisation number	1st	2nd	3rd	4th
Ionisation energy/kJ mol ⁻¹	738	1451	7733	10541

[1]

iv. The element which forms a compound with fluorine that has octahedral molecules.

[1]

v. An element which reacts with water to form an acidic solution.

[1]

vi. The element **X**, which forms a compound with hydrogen, **XH₃**, with a molar mass of 34.0 g mol⁻¹.

[1]

vii. An element which forms a compound with hydrogen in which the element has an oxidation number of -4.

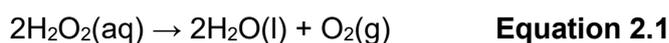
[1]

viii. The element which has a density of 1.33 × 10⁻³ g cm⁻³ at room temperature and pressure.

[1]

132. This question looks at reactions of hydrogen peroxide and of cobalt(II) ions.

Aqueous hydrogen peroxide decomposes as shown in **equation 2.1**.



The reaction is catalysed by manganese(IV) oxide, MnO₂.

A student investigates the decomposition of a hydrogen peroxide solution as outlined below.

- The student adds 50.00 cm³ of H₂O₂(aq) to a conical flask.
- The student adds a small spatula measure of MnO₂ and quickly connects the flask to a gas syringe.
- The student measures the volume of oxygen every 200 seconds.

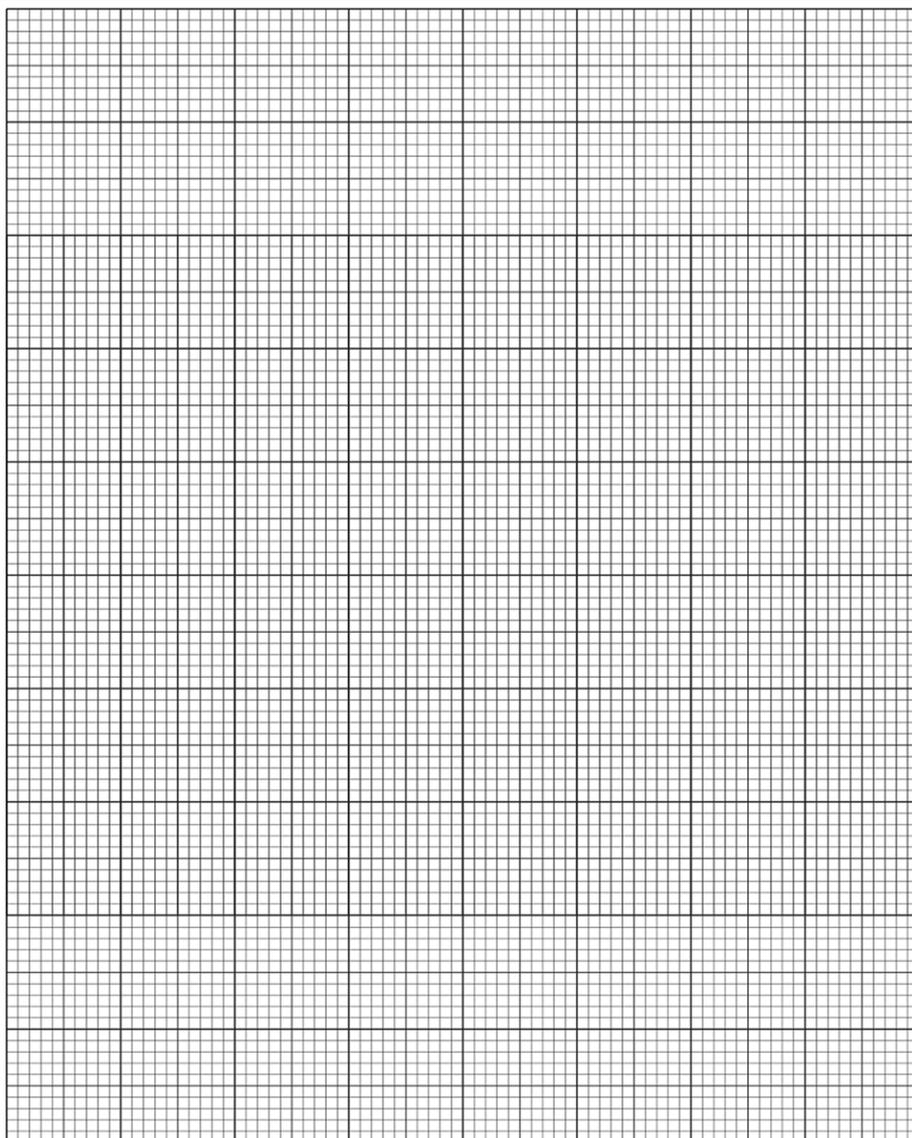
**Results**

Time/s	Volume of O ₂ /cm ³
0	0
200	15
400	28
600	36
800	41
1000	46
1200	48
1400	50

i. Process the results as outlined below.

- Plot a graph of **volume of O₂** against **time**.
 - Use your graph to find the rate of the reaction, in cm³ s⁻¹, at $t = 500$ s.
- Show your working on the graph and in the space below.

rate = _____ cm³ s⁻¹ [5]



- ii. The student allows the reaction in **equation 2.1** to proceed until no more gas is evolved. The volume of O_2 in the syringe is now 55 cm^3 , measured at RTP.

Calculate the initial concentration of the H_2O_2 .

Give your answer to **two** significant figures.

initial concentration of $H_2O_2 =$

mol dm^{-3} [3]



133. Ethanedioic acid, $(\text{COOH})_2$, is present in rhubarb leaves.

A student carries out a redox titration using aqueous cerium(IV) sulfate, $\text{Ce}(\text{SO}_4)_2(\text{aq})$, to determine the percentage, by mass, of ethanedioic acid in rhubarb leaves.

In the titration, $\text{Ce}^{4+}(\text{aq})$ ions oxidise ethanedioic acid in hot acid conditions:



$\text{Ce}^{4+}(\text{aq})$ ions have a yellow colour. $\text{Ce}^{3+}(\text{aq})$ ions are colourless.

The student weighs 82.68 g of rhubarb leaves and extracts ethanedioic acid from the leaves.

The ethanedioic acid is added to dilute sulfuric acid to form a colourless solution which is made up to 250.0 cm^3 with distilled water.

The student heats 25.00 cm^3 of this solution to $70 \text{ }^\circ\text{C}$ and titrates this volume with $0.0500 \text{ mol dm}^{-3}$ $\text{Ce}(\text{SO}_4)_2$ from the burette.

The student repeats the titration to obtain concordant (consistent) titres.

Titration results

The trial titre has been omitted.

	1	2	3
Final reading/ cm^3	24.30	47.80	23.65
Initial reading/ cm^3	1.05	24.30	0.50

- i. This titration is self-indicating and the student does not need to add an indicator.

What colour change would the student observe at the end point?

[1]

Colour change from _____ to _____

- ii. Calculate the percentage, by mass, of ethanedioic acid in the rhubarb leaves.

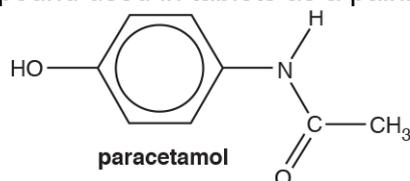
Give your answer to an **appropriate** number of significant figures.



percentage of ethanedioic acid =

% [6]

134. Paracetamol is a solid organic compound used in tablets as a painkiller.



i. Name the functional groups present in paracetamol.

[2]

ii. * A chemist prepares a pure solid sample of paracetamol from 4-nitrophenol in two stages:



Describe a two-stage synthesis of 5.00 g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%.

In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol.

[6]



135. Succinic acid $(\text{CH}_2\text{COOH})_2$ is esterified by ethanol, $\text{C}_2\text{H}_5\text{OH}$, in the presence of an acid catalyst to form an equilibrium mixture.

Succinic acid is esterified by ethanol, $\text{C}_2\text{H}_5\text{OH}$, in the presence of an acid catalyst to form an equilibrium mixture.

The equilibrium constant, K_c , for this equilibrium can be calculated using the amounts, in moles, of the components in the equilibrium mixture, using **expression 5.1**.

$$K_c = \frac{n(\text{CH}_2\text{COOC}_2\text{H}_5)_2 \times n(\text{H}_2\text{O})^2}{n(\text{CH}_2\text{COOH})_2 \times n(\text{C}_2\text{H}_5\text{OH})^2}$$

Expression 5.1

A student carries out an experiment to determine the value of K_c for this equilibrium.

- The student mixes together 0.0500 mol of succinic acid and 0.150 mol of ethanol, with a small amount of an acid catalyst.
- The mixture is allowed to reach equilibrium.
- The student determines that 0.0200 mol of succinic acid are present in the equilibrium mixture.

i. Which technique could be used to determine the equilibrium amount of succinic acid?

..... [1]

ii. Write the equation for the equilibrium reaction that takes place.

..... [1]

iii. Draw the skeletal formula of the ester present in the equilibrium mixture.



[1]

iv. K_c is the equilibrium constant in terms of equilibrium concentrations.

Why can **expression 5.1** be used to calculate K_c for this equilibrium?

[1]

v. Calculate the value of K_c for this reaction.

Show your working.

 $K_c =$

[3]

136. What is the number of oxygen atoms in 88.0 g of CO_2 ?

- A 3.01×10^{23}
- B 1.20×10^{24}
- C 2.41×10^{24}
- D 4.82×10^{24}

Your answer

[1]



137. A compound has the composition by mass:

H, 5.00%; N, 35.00%; O, 60.00%.

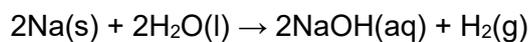
Which compound has this composition?

- A HNO₃
- B NH₄NO₃
- C HNO₂
- D NH₂OH

Your answer

[1]

138. Sodium reacts with water as shown below.



Which mass of sodium reacts with water to produce 960 cm³ of hydrogen gas at RTP?

- A 0.46 g
- B 0.92 g
- C 1.84 g
- D 3.68 g

Your answer

[1]



139. 1 mol of a compound reacts with 8 mol O_2 for complete combustion.

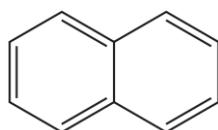
What is the formula of the compound?

- A C_4H_8
- B C_4H_9OH
- C $C_5H_{11}OH$
- D C_5H_{12}

Your answer

[1]

140. The structure of naphthalene is shown below.



What is the molecular formula of naphthalene?

- A $C_{10}H_8$
- B $C_{10}H_{10}$
- C $C_{12}H_{10}$
- D $C_{12}H_{12}$

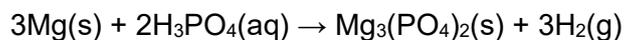
Your answer

[1]



141(a). This question is about compounds of magnesium and phosphorus.

A student plans to prepare magnesium phosphate using the redox reaction of magnesium with phosphoric acid, H_3PO_4 .



- i. In terms of the number of electrons transferred, explain whether magnesium is being oxidised or reduced.

[1]

- ii. The student plans to add magnesium to 50.0 cm^3 of 1.24 mol dm^{-3} H_3PO_4 .

Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid.

Give your answer to **three** significant figures.

mass of Mg = _____ g [3]

- iii. How could the student obtain a sample of magnesium phosphate after reacting magnesium with phosphoric acid?

[2]



- iv. Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium.

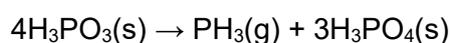
Choose a suitable magnesium compound for this preparation and write the equation for the reaction.

Formula of compound _____

Equation _____

[2]

- (b). Phosphine, PH_3 , is a gas formed by heating phosphorous acid, H_3PO_3 , in the absence of air.



- i. 3.20×10^{-2} mol of H_3PO_3 is completely decomposed by this reaction.

Calculate the volume of phosphine gas formed, in cm^3 , at 100 kPa pressure and 200 °C.

volume of PH_3 = _____ cm^3 [4]

- ii. When exposed to air, phosphine spontaneously ignites, forming P_4O_{10} and water.

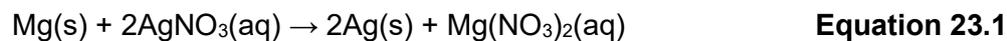
Construct an equation for this reaction.

..... [1]



142. This question is about energy changes and rate of reaction.

Magnesium reacts with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$, as in **equation 23.1**.



A student carries out an experiment to determine the enthalpy change of this reaction, $\Delta_r H$.

- The student adds 25.0 cm^3 of $0.512 \text{ mol dm}^{-3}$ AgNO_3 to a polystyrene cup.
- The student measures the temperature of the solution.
- The student adds a small spatula measure of magnesium powder, stirs the mixture and records the maximum temperature

Temperature readings

Initial temperature	= $19.5 \text{ }^\circ\text{C}$
Maximum temperature	= $47.5 \text{ }^\circ\text{C}$

- i. Calculate $\Delta_r H$, in kJ mol^{-1} , for the reaction shown in **equation 23.1**.

Give your answer to an **appropriate** number of significant figures.

Assume that the density and specific heat capacity, c , of the solution are the same as for water and that all the aqueous silver nitrate has reacted.

$\Delta_r H =$ _____ kJ mol^{-1} [4]



- ii. At the end of the experiment, the student adds a few drops of aqueous sodium chloride to the reaction mixture in the polystyrene cup to test whether all the aqueous silver nitrate has reacted.

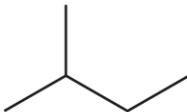
Explain how the results would show whether all the aqueous silver nitrate has reacted. Include an equation with state symbols in your answer.

[2]

143(a). This question is about saturated hydrocarbons.

Compounds **A**, **B** and **C** are saturated hydrocarbons.

The structures and boiling points of **A**, **B** and **C** are shown below.

	Isomer	Boiling point / °C
A		36
B		28
C		9

- Use the structures to explain what is meant by the term structural isomer.
- Explain the trend in boiling points shown by **A**, **B** and **C** in the table.



[5]

(b). Compounds **A**, **B** and **C** all react with chlorine in the presence of ultraviolet radiation to form organic compounds with the formula $C_5H_{11}Cl$.

i. Name the mechanism for this reaction.

[1]

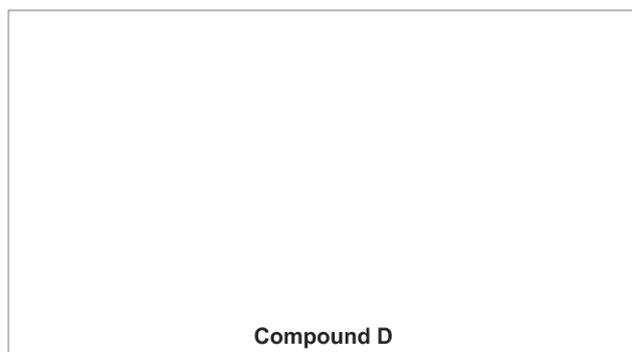
ii. Complete the table to show the number of structural isomers of $C_5H_{11}Cl$ that could be formed from the reaction of chlorine with **A** and **B**.

	A	B
Number of structural isomers

[2]

iii. The reaction of compound **A** with excess chlorine forms a compound **D**, which has a molar mass of 175.5 g mol^{-1} .

Draw a possible structure for compound **D** and write the equation for its formation from compound **A**. Use molecular formulae in the equation.

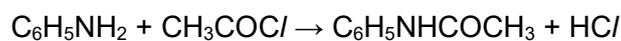


Equation

[2]



144. A student reacts 4.50 g of $C_6H_5NH_2$ with excess CH_3COCl in the reaction below.



$M_r = 93.0$

$M_r = 135.0$

The reaction produces 3.25 g of $C_6H_5NHCOCH_3$.

What is the percentage yield of $C_6H_5NHCOCH_3$?

- A 49.8
- B 68.9
- C 72.2
- D 95.4

Your answer

[1]

145(a). What mass of carbon dioxide (in g) is formed by the complete combustion of 42.0 m^3 (measured at RTP) of propane?

mass = g [2]

(b). What is the number of oxygen atoms in 4.26 g of P_2O_5 ?

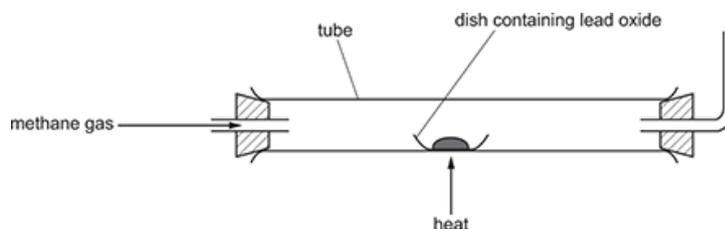
number of oxygen atoms = [2]



146. There are four oxides of lead: PbO , PbO_2 , Pb_2O_3 and Pb_3O_4 .

A student carries out an experiment to identify an unknown lead oxide, which is one of the four oxides of lead shown above.

The student plans to reduce the unknown lead oxide to lead by heating the lead oxide in a stream of methane gas, CH_4 . The apparatus is shown below.



Student's method

- Weigh an empty dish.
- Add the lead oxide to the dish and reweigh.
- Set up the apparatus and pass methane gas through the tube as shown.
- Heat the dish for 10 minutes.
- Pass cold air through the tube to cool the dish and contents.
- Weigh the dish and contents.

i. Write the equation for the reduction of Pb_2O_3 with CH_4 .

..... [1]

ii. The student uses safety glasses and a lab coat.

State, with a reason, **one** other important safety precaution the student should take when carrying out this experiment.

..... [1]



- iii. The student was not sure that all the oxygen had been removed from the lead oxide.

Suggest **two** modifications that the student could make to their method to be confident that all the oxygen had been removed. Explain your reasoning.

1

2

[2]

- iv. The student makes suitable modifications to the method and repeats the experiment to obtain the accurate results shown below.

Mass of dish / g	8.364
Mass of dish + lead oxide / g	11.818
Mass of dish + lead at end of experiment / g	11.496

Calculate the empirical formula of the lead oxide.

empirical formula = [2]



147. One molecule of a gas has a mass of 2.658×10^{-23} g.

What is a possible formula of the gas?

- A CH₄
- B O₂
- C SO₂
- D SO₃

Your answer

[1]

148. 3.528 g of a Group 2 metal, **M**, is reacted with an excess of chlorine. The reaction forms 9.775 g of a chloride.

What is metal **M**?

- A magnesium
- B calcium
- C strontium
- D barium

Your answer

[1]



149. What is the percentage composition by mass of nitrogen in $(\text{NH}_4)_2\text{CO}_3$?

- A 14.58%
- B 17.95%
- C 29.17%
- D 37.50%

Your answer

[1]

150. Which chemical process is the most sustainable in terms of the atom economy of the organic product?

- A $\text{CO}_2 + 3\text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}$
- B $\text{CH}_3\text{CH}_2\text{OH} + \text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{CH}_3\text{CH}_2\text{Cl} + \text{NaHSO}_4 + \text{H}_2\text{O}$
- C $\text{CH}_3\text{CH}_2\text{Br} + \text{NaOH} \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{NaBr}$
- D $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2 + \text{H}_2\text{O}$

Your answer

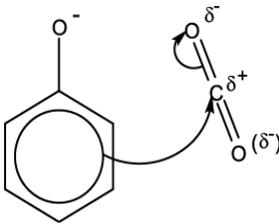
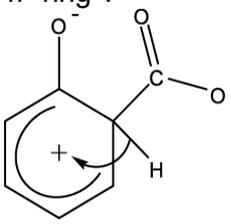
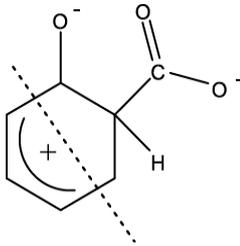
[1]

END OF QUESTION PAPER

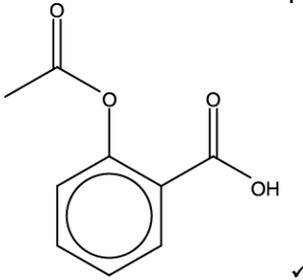
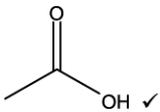


		<p>Product from HC/(aq)</p>		
		<p>Product from excess CH₃OH/H₂SO₄</p>		<p>Note: the amine group could be shown as either NH₂ or NH₃⁺ (<i>acidic conditions</i>)</p> <p>ALLOW one mark for</p>
		<p>Molar mass of G = $\frac{3.51}{0.0300} = 117(.0) \text{ (g mol}^{-1}\text{)}$ ✓</p>		
	ii	<p>Structure of G</p>	6	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW R (group of G) is -CH(CH₃)₂ if structure of amino acid is not given</p>
		Total	6	
79	a i	<p>Dipole shown on C=O bond, C^{δ+} and O^{δ-}, AND curly arrow from the C=O bond to the</p>	3	ANNOTATE ANSWER WITH TICKS AND CROSSES



		<p>$O^{\delta-}$ atom AND Curly arrow from π-bond to C in CO_2 ✓</p>  <hr/> <p>Correct intermediate ✓</p> <p>Curly arrow back from C-H bond to reform π-ring ✓</p> 		<p>DO NOT ALLOW the following intermediate:</p>  <p>π-ring must cover more than 1/2 of the ring AND 'horseshoe' in the correct orientation, <i>ie</i> gap towards C with COO^- ALLOW + sign anywhere inside the 'hexagon' of intermediate</p>
	ii	<p>Neutralisation ✓</p> <p>(In Stage 1) phenol loses H^+ AND (In Stage 3) carboxylate ion gains H^+ ✓</p>	2	<p>ALLOW acid-base</p> <p>ALLOW both Stage 1 AND Stage 3 involve proton transfer</p>
	iii	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 7.31 (g) award 3 marks</p> <hr/> <p>actual</p> $n(\text{salicylic acid}) \text{ produced} = \frac{4.83}{138} = 0.035(0)$ <p>(mol) ✓</p>	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW ECF at each stage</p> <p>ALLOW 3 SF up to calculator value correctly rounded for intermediate values</p> <p>100 ALLOW expected mass compound E = $\frac{100}{100} \times 4.83 \times 45.0 = 10.733$ (g)</p>



		<p>theoretical</p> $n(\text{phenol}) = n(\text{salicylic acid}) = \frac{0.035(0) \times 45.0}{100} = 0.0778 \text{ (mol)} \checkmark$ <p>Mass of phenol = $0.0778 \times 94.0 = 7.31 \text{ (g)} \checkmark$</p>		<p>ALLOW Mass phenol reacted = $0.035 \times 94.0 = 3.29 \text{ (g)}$</p> <p>ALLOW Mass of phenol used = $3.29 \times \frac{100}{45.0} = 7.31 \text{ (g)}$</p> <p>Note: 1.48 g would get 2 marks <i>(use of 45.0/100 instead of 100/45.0)</i> 7.30 g would get 2 marks <i>(use of 0.0777 for moles phenol)</i></p>
	b	<p>Skeletal formula of aspirin</p>  <p>Skeletal formula of ethanoic acid</p> 	2	<p>IF skeletal formulae are not used ALLOW one mark if both the structures of aspirin AND ethanoic acid are correct</p> <p>IGNORE names</p>
		Total	10	
80		<p><i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) Structure of J identified as $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)_2\text{CN}$ AND/OR A comprehensive analysis with most of the spectral data analysed and few omissions.</p>	6	<p>LOOK ON THE SPECTRA for labelled peaks. Indicative scientific points may include:</p> <p><u>Empirical and Molecular Formula of J</u></p> $\text{C} : \text{H} : \text{N} = \frac{74.17}{12} : \frac{11.41}{1} : \frac{14.42}{14}$ $6.18 : 11.41 : 1.03$ $\circ \quad 6 : 11 : 1$



		<p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Analysis may be incomplete and structure of J identified. OR Thorough analysis of one aspect of the information given in question and structure of J may be incorrectly identified.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) An attempt at a simple analysis. OR Explains one scientific point thoroughly with a few omissions.</p> <p><i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i></p> <p>0 marks No response or no response worthy of credit.</p>		<ul style="list-style-type: none"> Empirical formula of J = $C_6H_{11}N$ uses $m/z = 97.0$ and empirical formula to determine molecular formula of J as $C_6H_{11}N$ <p><u>1H NMR spectrum</u></p> <ul style="list-style-type: none"> $\delta = 0.9$ ppm, triplet, $CH_3-CH_2-(C-)$ $\delta = 1.4$ ppm, singlet, $(CH_3)_2 C^-$ $\delta = 1.6$ ppm, quartet, $CH_3-CH_2^- (C-)$ <p><u>IR Spectrum and Structure of J</u></p> <ul style="list-style-type: none"> peak at 2220–2260 (cm^{-1}) is $C\equiv N$ Correct structure of J $ \begin{array}{c} CH_3 \\ \\ CH_3-CH_2-C-CN \\ \\ CH_3 \end{array} $ <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p>
		Total	6	
81	a	$n(H_2O) = 27.55/18.0 = 1.5306 \text{ (mol)} \checkmark$ $n((NH_4)_2Fe(SO_4)_2) = 72.45/284.0 = 0.2551 \text{ (mol)} \checkmark$	3	<p>If there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW calculator value or rounding to two significant figures or more but IGNORE 'trailing zeroes' if wrong <i>M</i> produces such numbers throughout.</p> <p>ALLOW ECF</p>



		<p>whole number ratio of $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 : \text{H}_2\text{O}$ $= 0.2551 : 1.5306 = 1 : 6$ OR $x = 6 \checkmark$</p>		<p>If no working, ALLOW 1 mark for $x = 6$.</p>
	b i	To neutralise acidic soil \checkmark	1	
	ii	<p><i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) Describes practical details of tests and observations that allows all four ions to be identified AND Attempts associated equations, with most correct.</p> <p><i>There is a well-developed line of reasoning and the method is clear and logically structured. The information presented is relevant and substantiated by observations from the tests described and practical details.</i></p> <p>Level 2 (3–4 marks) Describes most practical details of tests including the observations that allows most ions to be identified AND Attempts associated equations, with some correct.</p> <p><i>There is a line of reasoning presented and the method has some structure. The information presented is in the most-part relevant and supported by some evidence of observations from the tests described but practical details may be absent.</i></p> <p>Level 1 (1–2 marks) Describes some of the practical details of tests and observations would only allow some ions to be identified. OR Attempts associated equations, with some correct.</p> <p><i>The information is basic and the method lacks structure. The information is supported by limited evidence of the observations, the</i></p>	6	<p>Indicative scientific points may include</p> <p>Practical details:</p> <ul style="list-style-type: none"> • Sample stirred with water and mixture filtered. • SO_4^{2-}, Fe^{2+}, NH_4^+ tests on filtrate. • CO_3^{2-} test on residue or garden product <p>Tests and associated equations: CO_3^{2-} test: <i>Test:</i> Add nitric acid. <i>Observation:</i> effervescence. <i>Equation:</i> $\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$ ALLOW $\text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ OR overall equation of CaCO_3 and an acid.</p> <p>SO_4^{2-} test: Add $\text{BaCl}_2(\text{aq})/\text{Ba}(\text{NO}_3)_2(\text{aq})/\text{Ba}^{2+}(\text{aq})$. Observation: white precipitate. Equation: $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$</p> <p>$\text{Fe}^{2+}$ test: Test: Add $\text{NaOH}(\text{aq})$ Observation: green precipitate Equation: $\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2$</p> <p>$\text{NH}_4^+$ test: Test: Add $\text{NaOH}(\text{aq})$ and warm Observation: gas turns red litmus indicator blue Equation: $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$</p>



		<p>relationship to the evidence may not be clear.</p> <p>0 marks No response or no response worthy of credit.</p>								
		Total	10							
82	a	<p>Iodine (solution) has a yellow/orange/brown colour</p> <p>AND</p> <p>Concentration of I₂ decreases/I₂ is used up ✓</p>	1	ALLOW products are colourless						
	b	<table border="1"> <thead> <tr> <th>Time/s</th> <th>[I₂(aq)]/mol dm⁻³</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0.0100 ✓</td> </tr> <tr> <td>500</td> <td>0.00225 ✓</td> </tr> </tbody> </table>	Time/s	[I ₂ (aq)]/mol dm ⁻³	0	0.0100 ✓	500	0.00225 ✓	2	<p>ALLOW 0.01 and 0.010</p> <p>ALLOW 0.0023</p>
Time/s	[I ₂ (aq)]/mol dm ⁻³									
0	0.0100 ✓									
500	0.00225 ✓									
	c i	<p>Axes labelled with units AND linear scales AND at least half of the graph paper used ✓</p> <p>Points correctly plotted ✓</p> <p>Best fit straight line ✓</p>	3	Each point must be within one small square on graph paper of value in table						
	ii	<p>Order = 0 ✓</p> <p>Straight line graph shows rate is constant throughout</p>	2							



		<p>OR rate does not depend on $[I_2]$ ✓</p>		
	d	<p>Step 1:</p> $H_3C-\overset{\overset{O}{\parallel}}{C}-CH_3 + H^+$ $\longrightarrow H_3C-\overset{\overset{+}{OH}}{\parallel}{C}-CH_3 \checkmark$ <p>Step 3:</p> $H_3C-\overset{\overset{OH}{ }}{C}=CH_2 + I_2$ $\longrightarrow H_3C-\overset{\overset{O}{\parallel}}{C}-CH_2I + HI \checkmark$	2	<p>ALLOW correct molecular, structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous</p>
		Total	10	
83	a	<p><i>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) A comprehensive analysis of the information available with through explanations linked to the evidence. Acid C identified as a tricarboxylic acid with a tertiary –OH group and the correct molecular formula of $C_6H_8O_7$.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated</i></p> <p>Level 2 (3–4 marks) Analysis of the information available but explanations may be incomplete or there may be mistakes in calculations, although the method may be sound.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) A simple analysis of the information available and limited explanations which</p>	6	<p>Indicative scientific points may include</p> <p>Identification of functional groups</p> <ul style="list-style-type: none"> • Tribasic acid → three –COOH groups <i>From 1 mol C requires 3 mol NaOH</i> • Tertiary alcohol <i>From no colour change with hot acidified dichromate(VI)</i> <p>Determination of molecular formula of C</p> <ul style="list-style-type: none"> • $M(C) = \frac{2.323}{1.21 \times 10^{-2}} = 192 \text{ (g mol}^{-1}\text{)}$ <i>From 1.21 × 10⁻² mol C has a mass of 2.323 g.</i> • $192 - 3 \times 45 \text{ (3} \times \text{COOH)} - 16 \text{ (O)} = 41 \text{ 41} \rightarrow C_3H_5$ <i>(or evidence of working)</i> • Molecular formula = $C_6H_8O_7$ <p>Structure of citric acid</p> <ul style="list-style-type: none"> • 4 peaks in ^{13}C NMR → 4 types of carbon • Correct structure of C matching evidence.



		<p>may or may not be explicitly linked to the evidence.</p> <p><i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i></p> <p>0 marks – No response worthy of credit.</p>		$\begin{array}{c} \text{COOH} \\ \\ \text{HOOC}-\text{CH}_2-\text{C}-\text{CH}_2-\text{COOH} \\ \\ \text{OH} \end{array}$ <p>NOTE: Structure below match all evidence except for ^{13}C NMR. See Level 3 criteria.</p> $\begin{array}{cc} \begin{array}{c} \text{COOH} \\ \\ \text{HO}-\text{C}-\text{CH}_2-\text{CH}_2-\text{COOH} \\ \\ \text{COOH} \end{array} & \begin{array}{c} \text{COOH} \\ \\ \text{HOOC}-\text{C}-\text{CH}-\text{COOH} \\ \quad \\ \text{OH} \quad \text{CH}_3 \end{array} \end{array}$
	b i	$\text{C}_2\text{H}_3\text{O}_3$ ✓	1	
	ii	2,3- dihydroxybutanedioic acid ✓	1	<p>ALLOW 2,3-dihydroxybutane-1,4-dioic acid</p> <p>ALLOW absence of hyphens or extra hyphen or space, e.g. 2,3-dihydroxy butanedioic acid</p> <p>ALLOW full stops or spaces between numbers e.g. 2.3 dihydroxybutanedioic acid</p>
	iii	$\begin{array}{ccccccccccc} & \text{O} & \text{OH} & \text{H} & \text{O} & & & & & & \\ & & & & & & & & & & \\ \text{---} & \text{C} & \text{---} & \text{C} & \text{---} & \text{C} & \text{---} & \text{C} & \text{---} & \text{N} & \text{---} & (\text{CH}_2)_6 & \text{---} & \text{N} & \text{---} \\ & & & & & & & & & & & & & & \\ & & \text{H} & \text{OH} & & & & \text{H} & & \text{H} & & & & \text{H} & \end{array}$ <p>Correct amide link ✓</p> <p>Rest of structure ✓</p>	2	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>'End bonds' MUST be shown</p> <p>IGNORE brackets</p> <p>IGNORE n</p>
	iv	<p>$[\text{H}_3\text{N}^+(\text{CH}_2)_6\text{NH}_3^+] [\text{ }^-\text{OOC}(\text{CHOH})_2\text{COO}^-]$</p> <p>OR $[\text{H}_3\text{N}(\text{CH}_2)_6\text{NH}_3]^{2+} [\text{OOC}(\text{CHOH})_2\text{COO}]^{2-}$</p> <p>Positive ion correct ✓</p> <p>Negative ion correct ✓</p>	2	<p>ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous</p> <p>ALLOW charge either on N atom or NH_3^+</p> <p>Negative charge must be on COO^-</p> <p>ALLOW $[\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_3^+] [\text{ }^-\text{OOC}(\text{CHOH})_2\text{COOH}]$</p>
		Total	12	
84		<p>FIRST CHECK ANSWER ON THE ANSWER LINE</p> <p>IF answer = 13.4 (m³) award 5 marks</p> <p>Amounts of FeS₂ and SO₂</p> <p>$n(\text{FeS}_2) = \frac{0.0300 \times 10^6}{120}$ OR 250 (mol)✓</p>	1	<p>If there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW ECF from incorrect amount of FeS₂ e.g. incorrect M for FeS₂ could still score 4 marks</p> <p>.....</p>



		$n(\text{SO}_2) = 2 \times 250 = 500 \text{ (mol)} \checkmark$ Pressure unit conversion Use of $p = 100 \times 10^3 \text{ (Pa)} \checkmark$ Ideal gas equation $V = \frac{nRT}{p}$ OR $V = \frac{500 \times 8.314 \times 323}{100 \times 10^3}$ AND Use of $T = 323 \text{ K} \checkmark$ Final answer $V = 13.4 \text{ (m}^3\text{)} \checkmark$ Must be to 3 SF	1	Common Errors No T conversion 4marks $V = 2.08 \text{ (m}^3\text{)}$
			1	No p conversion 4 marks $V = 13\,400 \text{ m}^3$
			1	No p AND T conversion 3 marks $V = 2080 \text{ m}^3$
			1	No 3 SF 4 marks $V = 13.42711 \text{ (m}^3\text{)} \text{ OR } 4 \text{ SF and more}$
			1	No $\times 2$ for $n(\text{SO}_2)$ AND 3SF 4 marks $V = 6.71 \text{ (m}^3\text{)}$
		Total	5	
85		B	1	ALLOW 20 in the box
		Total	1	
86		C	1	
		Total	1	
87		A	1	
		Total	1	
88		C	1	ALLOW 4.1 in the box
		Total	1	
89		C	1	Examiner Comments The first question on the paper to require the application of some mathematical skills proved slightly more testing although the correct response C was given by a majority of candidates. The most common incorrect answer was B which has the same number of carbon and hydrogen atoms in its formula. This may have resulted from the question stating that an equal volume of both carbon dioxide and water was produced in the reaction, and the failure to consider the stoichiometry of the equation.
		Total	1	
90		D	1	Examiner Comments This was a fairly easy question and the vast majority of candidates knew that addition, with 100% atom economy based on only one



					product being formed, had the highest atom economy of the four reaction types listed. Candidates who failed to score this mark randomly choose one of the other distractors.
			Total	1	
91			C	1	Examiner Comments The vast majority of candidates were able to determine the molecular formula of the compound on what proved to be one of the easiest of the multiple choice questions.
			Total	1	
92			A	1	Examiner Comments Candidates across the whole ability range appeared to find the question equally challenging. The common incorrect answer B, resulted from a failure to use the information that equal moles of acid were reacted with equal moles of alkali to produce an equal number of moles of water.
			Total	1	
93			<p><i>Please refer to marking instructions on page 5 of mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) All three scientific points are covered in detail and explained thoroughly.</p> <p><i>The method is logically structured and clear calculations are shown for an appropriate mass of metal and suitable volume of acid. The drawing of a tangent and determination of the gradient is communicated well.</i></p> <p>Level 2 (3–4 marks) Candidates cover all three scientific points but explanations may be incomplete. OR Two of the scientific points are described thoroughly with no omissions.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. e.g. there are clear calculations to justify mass and acid volume supported by</i></p>	6	Indicative scientific points 1. Method <ul style="list-style-type: none"> measure mass of (excess) zinc (using 2 decimal place balance) measure volume of hydrochloric acid (using measuring cylinder) mix zinc and acid in flask measure gas volume at time intervals 2. Calculations <ul style="list-style-type: none"> moles of hydrogen $72/24000 = 0.00300 \text{ mol}$ minimum mass of zinc $0.003 \times 65.4 = 0.20 \text{ g}$ moles of hydrochloric acid $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$ $0.00300 \times 2 = 0.00600 \text{ mol}$ volume / concentration of acid If $[\text{HCl}(\text{aq})] = 0.1 \text{ mol dm}^{-3}$ appropriate volume of acid = $0.006 \times 1000/0.1 = 60 \text{ cm}^3$ If $[\text{HCl}(\text{aq})] \geq 0.3 \text{ mol dm}^{-3}$, too low ($\leq 20 \text{ cm}^3$)



some working and units; a simple description for determining initial rate related to tangent but no detail of how to measure gradient..

Level 1 (1–2 marks)

There is a description based on at least two of the main scientific points

OR

The candidate explains one scientific point thoroughly with few omissions.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

e.g. 'add zinc and acid and measure volume (no mass, volume or time intervals); calculations that have little structure, absent units and little working.

0 marks

No response or no response worthy of credit.

If $[\text{HCl}(\text{aq})] \leq 0.03 \text{ mol dm}^{-3}$ too high ($\geq 200 \text{ cm}^3$)

3. Processing results

- Plot a graph of volume against time
- Draw a tangent at $t = 0$
- Gradient of tangent = initial rate
- Gradient = volume / time

Examiner's Comment:

This question was marked using a level of response mark scheme and relatively few candidates were able to achieve Level 3. Many vague and rambling responses failed to mention the basic requirement to measure the volume of gas at regular time intervals. Some preferred to record the change in mass and ignored the diagram with a labelled gas syringe, while some carried out the experiment in a measuring cylinder. The question advises candidates to show working in their calculations but many omitted calculations from their answer. The question asked for an explanation of how the results could be processed graphically but this section was often lacking detail. Level 1 responses usually included the measurement and mixing of reactants and an attempt at processing the results by plotting a graph but further detail was missing. Candidates achieving Level 2 usually included a calculation of the moles of reactants and a more detailed description of how to process the results. Some excellent Level 3



					responses included a full calculation of the mass of zinc and volume of hydrochloric acid required for the experiment.
			Total	6	
94			D	1	Examiner's Comments Most candidates answered this question correctly with only the weakest candidates losing the mark. Some candidates incorrectly identified the answer as B, which has the same ratio but was not the simplest whole number ratio.
			Total	1	
95			B	1	Examiner's Comments Able candidates answered this question correctly, with answer option A being a common distractor.
			Total	1	
96			C	1	Examiner's Comments This question was generally answered well. Answer option D was a common distractor.
			Total	1	
97			C	1	Examiner's Comments Most successful candidates showed rough working at the side with the formula displayed.
			Total	1	
98	a		Empirical formula Mole Ratio C : H : O = 5.88 : 5.92 : 1.47 ✓ Empirical formula = C ₄ H ₄ O ✓ Molecular formula Molecular formula = C ₈ H ₈ O ₂ AND	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW $\frac{70.58}{12.0} : \frac{5.92}{1.0} : \frac{23.50}{16.0}$ ALLOW 4:4:1 if linked to C:H:O Alternative method for 3 marks:

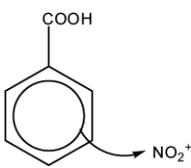
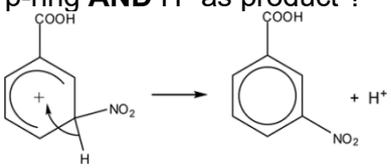
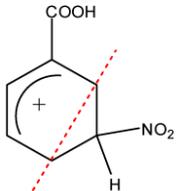


		Evidence of 136 in working or from labelled peak in spectrum ✓		<p>C: $\frac{136 \times 70.58/100}{12.0} = 8$</p> <p>H: $\frac{136 \times 5.92/100}{1.0} = 8$</p> <p>O: $\frac{136 \times 23.50/100}{16.0} = 2$</p> <p>Examiner Comments The empirical formula was correctly calculated by all but the weakest candidates. The final mark was more difficult to obtain as it required evidence that the molar mass had been determined from the mass spectrum and used in establishing the molecular formula.</p>
	b	<p>Functional groups</p> <p>Phenol AND ketone ✓</p> <p>Explanation Links phenol to (weak) acidity AND no reaction with Na₂CO₃ (so not carboxylic acid) ✓</p> <p>Links 2,4-DNP(H) or Brady's reagent observation to carbonyl AND</p> <p>Tollens' reagent observation (so not an aldehyde) ✓</p>	3	<p>DO NOT ALLOW any other functional groups for first marking point. ALLOW identity of functional groups in the explanation if not stated on functional group prompt line.</p> <p>ALLOW "aldehyde or ketone" in place of carbonyl</p> <p>Examiner Comments Many candidates were able to suggest that the compound contained a ketone but found it more difficult to indicate the presence of phenol. Approximately 20% of the entry obtained all three marks. When explaining the presence of the ketone some failed to indicate that the 2,4-DNP test indicated that the compound must contain a carbonyl and just focused on the lack of reactivity with Tollens'. Answers suggesting the molecule contained a ketone as no reaction was observed with Tollens' did not gain credit when no reference to carbonyl was seen. Those who recognised the presence of a phenol explained that the only acidic functional group that does not react with sodium carbonate is a phenol.</p>
	c	<p>Carbon NMR analysis</p> <p>Peaks between 110–160 ppm are the (four) aromatic (carbon environments) ✓</p> <p>Compound contains a C=O between 190 – 200 ppm</p>	3	<p>ALLOW peaks to be identified by:</p> <ul style="list-style-type: none"> • Peaks labelled on spectrum • Peaks indicated on a chemical structure • Peaks indicated from within text



		<p>AND Compound contains a C-C at 20 – 30 ppm ✓</p> <p>Structure</p>		<p>Note: If identifying aromatic peaks from the spectrum all four peaks should be indicated. ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>Examiner Comments When interpreting a carbon-13 NMR spectrum, candidates should be advised to fully label any peaks. Many candidates failed to indicate the presence of four aromatic peaks yet produced a structure containing a benzene ring. In some cases candidates did not link their answer to part (a) of the question giving structures that did not match their molecular formula.</p>
		Total	9	
99	i	<div style="border: 1px solid black; height: 40px; width: 100%;"></div> $n(\text{myrcene}) = \frac{204 \times 10^{-3}}{136.0} = 1.5(0) \times 10^{-3} \text{ (mol)} \checkmark$ $\text{Volume of H}_2 = 3 \times 1.5(0) \times 10^{-3} \times 24000 = 108 \text{ (cm}^3\text{)} \checkmark$	2	<p>Correct working required for the first marking point.</p> <p>ALLOW ECF from incorrect moles of myrcene i.e. $n(\text{myrcene}) \times 3 \times 24000$</p> <p>Common incorrect answers</p> <p>108000 cm³ = 1 mark (not converted to g) 12cm³ = 1 mark (divided by 3) 36 cm³ = 1 mark (not multiplied by 3)</p> <p>IGNORE Calculations based on $pV = nRT$</p> <p>Examiner Comments The best answers first converted 204 mg into g and then divided this value by the molar mass of myrcene. Candidates then linked this to presence of three double bonds and calculated correctly the moles of hydrogen required to produce the saturated alkene. Finally the moles were multiplied by 24000 cm³ to provide an answer in cm³. Candidates who worked in mg could not access the first mark however the subsequent mark was awarded as error carried forward. Answer = 108 cm³</p>
	ii	<p>Amount of hydrogen</p> $n(\text{H}_2) = \frac{5.28}{24.0} = 0.22(0) \text{ (mol)} \checkmark$ <p>Number of double bonds</p>	4	<p>ALLOW Evidence of $n(\text{H}_2) = \frac{5.28}{24.0}$ if 0.22 is not seen</p> <p>Evidence for 11 double bonds could come from 11H₂ in equation</p>



		$= \frac{0.220}{0.0200} = 11 \checkmark$ <p>Formula of saturated product</p> <p>$C_{40}H_{78}$</p> <p>Equation</p> <p>$C_{40}H_{56} + 11H_2 \longrightarrow C_{40}H_{78} \checkmark$</p>		<p>Formula could be shown as the product of an equation</p> <p>ALLOW ECF from $C_{40}H_{82}$ and $C_{40}H_{80}$ only i.e. $C_{40}H_{60} + 11H_2 \longrightarrow C_{40}H_{82}$ $C_{40}H_{58} + 11H_2 \longrightarrow C_{40}H_{80}$</p> <p>Examiner Comments The most common score on this question was two, with candidates being able to calculate the moles of hydrogen gas and relate this to the replacement of eleven double bonds. Frequently candidates calculated the formula of the saturated hydrocarbon to be $C_{40}H_{82}$ by applying the general formula C_nH_{2n+2} to a compound containing 40 carbon atoms. The best Candidates were able to adjust this formula to account for the presence of the two rings and were then able to write the correct equation for the hydrogenation</p>
		Total	6	
10 0	i	<p>Generation of electrophile</p> <p>$HNO_3 + H_2SO_4 \longrightarrow H_2O + HSO_4^- + NO_2^+ \checkmark$</p> <p>Electrophilic substitution</p> <p>Curly arrow from p-bond to NO_2^+ ?</p>  <p>-----</p> <p>Correct intermediate ?</p> <p>Curly arrow back from C-H bond to reform p-ring AND H^+ as product ?</p>  <p>Regeneration of catalyst</p>	5	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW $HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + 2HSO_4^- + NO_2^+$</p> <p>ALLOW $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ Then $H_2NO_3^+ \rightarrow H_2O + NO_2^+$</p> <p>ALLOW $^+NO_2$ OR NO_2^+</p> <p>First curly arrow must come from the ring to NO_2^+ DO NOT ALLOW the following intermediate:</p> 



		$\text{H}^+ + \text{HSO}_4^- \longrightarrow \text{H}_2\text{SO}_4 \checkmark$	<p>p-ring should cover approximately 4 of the 6 sides of the benzene ring structure AND the correct orientation, <i>i.e.</i> gap towards C with NO_2</p> <p>ALLOW + sign anywhere inside the 'hexagon' of intermediate Examiner Comments The majority of candidates were well prepared for this standard mechanism and frequently scored marks of four or five. Most were able to show equations to generate the electrophile and regenerate the catalyst. Candidates should note the importance of the correct placement of curly arrows and the horseshoe in the intermediate to show the remaining electrons present in the ring structure. These were often poorly represented, leading to marks not being awarded.</p>
	ii	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) Outlines the main steps of recrystallisation to produce a pure sample of 3-nitrobenzoic acid from the impure solid. AND Calculates correct percentage yield of 3-nitrobenzoic acid. AND Method of checking purity to include comparison to relevant data. <i>A well-structured response with the steps for recrystallisation and the determination of purity being given in the correct order. Correct use of terminology throughout.</i></p> <p>Level 2 (3–4 marks) Attempts all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with very few omissions. <i>The description of checking for purity or recrystallisation is clear and any calculations structured. Key terminology used</i></p>	<p>Indicative scientific points, with bulleted elements, may include:</p> <p>1. Purification</p> <ul style="list-style-type: none"> Recrystallisation Dissolve impure solid in minimum volume of hot water/solvent Cool solution and filter solid Wash with cold water/solvent and dry <p>2. Percentage yield</p> <ul style="list-style-type: none"> $n(\text{benzoic acid}) \text{ used} = \frac{4.97}{122} = 0.0407 \text{ (mol)}$ $n(3\text{-nitrobenzoic acid}) \text{ made} = \frac{4.85}{167} = 0.0290 \text{ (mol)}$ percentage yield = $\frac{0.0290}{0.0407} \times 100 = 71.3 \text{ (\%)}$ <p>ALLOW 71 to calculator value of 71.29001554 correctly rounded.</p> <p>CHECK for extent of errors by ECF</p> <p>Alternative correct calculation may calculate theoretical mass of 3-nitrobenzoic acid that can be produced as $0.0407 \times 167 = 6.80 \text{ (g)}$ followed by: percentage yield = $\frac{4.85}{6.80} \times 100 = 71.3 \text{ (\%)}$</p>



	<p><i>appropriately.</i></p> <p>Level 1 (1–2 marks) A simple explanation based on at least two of the main scientific points. OR Explains one scientific point thoroughly with few omissions. <i>There is an attempt at a logical structure. The description of the practical techniques provides some detail but may not be in the correct order.</i></p> <ul style="list-style-type: none"><i>Purification step is unclear with few scientific terms and little detail, e.g. just 'recrystallise'.</i><i>Calculation is difficult to follow, may just include a calculation of moles of reactants and/or products.</i><i>Purity check specifies a method but this is unclear with little detail, e.g. take melting point.</i> <p>0 marks No response or no response worthy of credit.</p>	<p>Calculation must attempt to calculate $n(\text{benzoic acid})$ in mol.</p> <p>3. Checking purity</p> <ul style="list-style-type: none">Obtain melting pointCompare to known valuesPure sample will have a (sharp) melting point very close to data book value <p>ALLOW alternative approach based on spectroscopy or TLC</p> <p>Spectroscopy</p> <ul style="list-style-type: none">Run an NMR/IR spectrumCompare to (spectral) databaseSpectrum of pure sample will contain same peaks and not others <p>TLC</p> <ul style="list-style-type: none">Run a TLCCompare (R_f value) to known dataPure sample will have a very similar R_f <p>Examiner Comments This question tested some of the practical techniques covered as part of the practical endorsement as well as requiring candidates to calculate a percentage yield for the reaction. This proved to be quite a challenging question with some candidates giving little detail of how to carry out a recrystallisation. Common answers included a statement that the solid should be allowed to dissolve in a solvent and then filtered to obtain crystals. This did not gain credit for the scientific content as there was no indication of the solid dissolving in a hot solvent and then being allowed to cool before carrying out filtration. High quality answers often went above and beyond the requirements of the marking scheme with some candidates discussing the importance of dissolving in the minimum amount of hot solvent to obtain a saturated solution, the need to wash and dry</p>
--	--	---



				<p>the crystals and provided detail of the apparatus and or method required.</p> <p>Most candidates discussed that purity could be determined by taking the melting point of the product and comparing this to a value obtained from data book. The most comprehensive answers gave an indicated of the apparatus required to carry out the melting point determination and discussed how the melting point becomes higher and sharper as impurities are removed. Common errors included comments about carrying out a boiling point determination.</p> <p>When carrying out a percentage yield calculation, it is important to round answers only at the last stage of the calculation. Early rounding frequently led candidates to obtain answers, which did not gain credit. Weaker Candidates divided the mass of 3-nitrobenzoic acid by the mass of benzoic acid and obtained an answer of 97.6%. Answer = 71.3%</p>
		Total	11	
10 1	i		<p>2</p> <p>Examiner Comments All but the weakest candidates scored two marks for the two monomers that could be used to produce Nylon 6,6.</p>	
	ii	$(n = \frac{21500}{226} =) 95 \text{ (repeat units)}$	1	<p>MUST be a whole number. DO NOT ALLOW an answer that uses an incorrect molar mass in the working. ALLOW 96 Examiner Comments This was a fairly simple calculation where candidates were expected to divide the relative molecular mass of the polymer by the relative molecular mass of a single repeat unit (226) to establish the number of repeat units present in the polymer. Many candidates obtained the correct answer. Those that did</p>



				not gain credit made a simple error in their calculation of the relative molecular mass of the repeat unit. Answer 95
		Total	3	
10 2	a	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = CH₄•5.74 H₂O OR 5.74 award 2 marks</p> <p>.....</p> <p>Mole ratio</p> $n(\text{CH}_4) : n(\text{H}_2\text{O}) = \frac{13.4}{16.0} : \frac{86.6}{18.0}$ <p>OR 0.8375 : 4.811 ✓</p> <p>Formula</p> <p>CH₄•5.74 H₂O OR 5.74 ✓</p>	2	<p>Working to at least 3 SF but IGNORE 'trailing zeroes', e.g. ALLOW 16 for 16.0</p> <p>.....</p> <p>ALLOW algebraic approach, e.g. $n(\text{CH}_4) = n(\text{CH}_4 \cdot x\text{H}_2\text{O})$</p> $\frac{13.4}{16.0} = \frac{100}{16.0 + 18x}$ <p>x = 5.74</p> <p>ALLOW ECF from incorrect mole ratio</p> <p>.....</p> <p>For 1 mark, ALLOW x with < 2 DP:</p> <ul style="list-style-type: none"> • x = 5.7 • x = 6 • x = 5.73 from 0.8375 and 4.8 from 0.84 and 4.811 • x = 5.71 from 0.84 and 4.8 <p>Examiner's Comment: This part applied candidate's understanding of formula determination in a novel context. Although candidates were asked to show their value for x to two decimal places, many rounded their value to a whole number. Most candidates were awarded both marks for 5.74, but one mark for 6 was fairly common.</p> <p>Answer CH₄•5.74H₂O</p>
	b	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE</p> <p>IF answer = 188 (dm³) AND use of ideal gas equation Award 4 marks for calculation</p> <p>.....</p>	4	<p>ALLOW use of M(answer to (c) OR 119.32 <i>Examples</i></p>



$n(\text{CH}_4)$ in 1 kg

Rearranging ideal gas equation

$$V = \frac{nRT}{p} \checkmark$$

Substitution of values into $V = \frac{nRT}{p}$:

- Calculated value of $n(\text{CH}_4)$ (Use ECF)
- $R = 8.314$ OR 8.31

- T in K: 273 K

- p in Pa OR kPa 101 OR 101×10^3 OR 1.01×10^5

e.g. $\frac{8.375 \times 8.314 \times 273}{(101 \times 10^3)}$ OR $\frac{8.375 \times 8.314 \times 273}{101} \checkmark$

Final volume in dm^3 to 3 SF

$$V = 188 \text{ (dm}^3\text{)} \checkmark$$

COMMON ERRORS

Use of 298 K ALLOW ECF 3 marks max

Example $n(\text{CH}_4 \cdot 5.74 \text{ H}_2\text{O}) = 8.375 \checkmark \rightarrow 205 \text{ (dm}^3\text{)} \checkmark \checkmark$
 $V = \frac{8.375 \times 8.314 \times 298}{101 \times 10^3}$

Use of 24.0 dm^3 OR 22.4 dm^3 ALLOW ECF from $n(\text{CH}_4)$ 2 marks max for $n(\text{CH}_4)$ and V in dm^3

From $n(\text{CH}_4 \cdot 5.74 \text{ H}_2\text{O})$

$$\frac{1 \times 10^3}{119.32} = 8.38(1) \rightarrow 188 \text{ (dm}^3\text{)}$$

From $n(\text{CH}_4 \cdot 5.7 \text{ H}_2\text{O})$

$$\frac{1 \times 10^3}{118.6} = 8.43(2) \rightarrow 189 \text{ (dm}^3\text{)}$$

From $n(\text{CH}_4 \cdot 6 \text{ H}_2\text{O})$

$$\frac{1 \times 10^3}{124.0} = 8.06 \text{ (mol)} \rightarrow 181 \text{ (dm}^3\text{)}$$

.....
IF $V = \frac{nRT}{p}$ is omitted, ALLOW when

values are substituted into rearranged ideal gas equation.

Examiner's Comment:

The majority of candidates recognised that this problem involved the ideal gas equation, which was well known. Candidates usually rearranged the equation to make n the subject and substituted correct values into the equation. The examiners allowed error



		<p>24.0 $n(\text{CH}_4 \cdot 5.74 \text{ H}_2\text{O}) V = 8.375 \times 24.0$ $\text{dm}^3 = 8.375 \checkmark = 201 (\text{dm}^3) \checkmark$</p> <p>22.4 $n(\text{CH}_4 \cdot 5.74 \text{ H}_2\text{O}) V = 8.375 \times 22.4$ $\text{dm}^3 = 8.375 \checkmark = 188 (\text{dm}^3) \checkmark$</p> <p>13.4% (13.4/100) omitted 3 marks</p> <p>$n = \frac{1 \times 10^3}{16}$ $V = \frac{62.5 \times 8.314 \times 273}{101 \times 10^3}$ $= 62.5 (\text{mol}).$ $\rightarrow 1400 (\text{dm}^3) \checkmark \checkmark \checkmark$</p>	<p>carried forwards from the answer in 1(c) or an incorrectly calculated value for n. Common errors included an incorrect calculation of the amount of CH_4, n, or incorrect conversion into dm^3 for the final answer.</p> <p>A small number of candidates used 100 for 101 or 298 for 273.</p> <p>Instead of using the ideal gas equation, some weaker candidates resorted to use of 24.0 dm^3 or 22.4 dm^3, an approach that could still obtain two of the four available marks.</p> <p>Overall, the examiners were impressed with the responses seen to this part.</p> <p>Answer: 188 dm^3</p>
		Total	6
10 3	a	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) A comprehensive conclusion, using all quantitative data, to calculate the energy change and ΔH values for reactions 3.1 and 3.2 AND linking ΔH data using Hess' Law</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The working throughout is clearly shown. All values calculated with reasonable numbers of SF and correct signs mostly shown, allowing for ECF.</i></p> <p>Level 2 (3–4 marks) Attempts to describe all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with few omissions.</p> <p><i>There is a line of reasoning with some logical structure. There may be minor errors in energy change and errors in the calculations of ΔH for reaction 3.1 or reaction 3.2.</i></p> <p>Level 1 (1–2 marks) Processes raw mass and temperature data and obtains a calculated value for the energy change using $mc\Delta T$ OR attempts to obtain values for two scientific points but explanations may be</p>	<p>Indicative scientific points may include: 1. Masses and ΔT from raw results</p> <ul style="list-style-type: none"> $m(\text{Na}_2\text{O}) = 1.24 (\text{g})$ $m(\text{solution}) = 25.75 (\text{g})$ $\Delta T = 35.0 (^\circ\text{C})$ <p>Energy change from $mc\Delta T$</p> <ul style="list-style-type: none"> energy released in J OR kJ $= 25.75 \times 4.18 \times 35.0$ $= 3767 (\text{J})$ OR 3.767 (kJ) (3.767225 unrounded) <p>.....</p> <p>6 2. $\Delta_r H$ for reaction 3.2</p> <ul style="list-style-type: none"> $n(\text{Na}_2\text{O}) = \frac{1.24}{62.0} = 0.0200 (\text{mol})$ $\Delta_r H \text{ value} = \frac{3767}{0.0200} = -188 (\text{kJ mol}^{-1})$ (-188.36125 unrounded) <p>3. $\Delta_r H$ for reaction 3.1</p> <ul style="list-style-type: none"> ΔH value for reaction 3.1 clearly linked to ΔH for reaction 3.2 and reaction 3.3 in energy cycle or an expression: $\Delta H (3.1) = \Delta H (3.2) + 2\Delta H (3.3)$ $\Delta H (3.1) = -188 + (2 \times -57.6)$ $= -188 - 115.2 = -303(.2) (\text{kJ mol}^{-1})$ (-303.56125 unrounded)



	<p>incomplete</p> <p><i>There is an attempt at a logical structure with a line of reasoning to obtain a value for energy change. There may be minor errors in calculation of energy change.</i></p> <p>0 marks – No response or no response worthy of credit.</p>	<p>Note Throughout, ALLOW ECF from previous value ALLOW omission of trailing zeroes</p> <p>Examiner's Comment: In this part, candidates were presented with the results of an enthalpy experiment and other related data. They were then required to determine two enthalpy changes, one directly from the experimental results, the other indirectly using Hess' Law. No guidance was supplied about how to carry out this analysis.</p> <p>The examiners were impressed with the many superb responses that linked all the information together to determine correct values for the two enthalpy changes.</p> <p>Most candidates attempted all aspects of the problem but often made mistakes, particularly with the Hess' Law extension or with incorrect signs.</p> <p>From the raw experimental data, most candidates calculated the two masses, even if they did not subsequently use both masses, and the temperature change. A common error was to use the wrong mass in the initial $mc\Delta T$ calculation with 25.0, 1.24 or (25.75 + 1.24) commonly seen. A small number tried to convert the temperature change to Kelvin by adding 273 and using 308 instead of 35 in the calculation.</p> <p>Many calculated the amount of Na_2O correctly and used 0.0200 appropriately to determine the enthalpy change of reaction. It was not uncommon for candidates to omit this step or to use 0.0400 instead of 0.0200, although it was difficult to see why.</p> <p>In the Hess' Law extension, it was common to see an incorrect cycle, using incorrect signs, or -57.6 being used rather than 2×-57.6.</p>
--	--	--



				<p>Generally, candidates need to improve the use of signs, units and in the quality how their answers are communicated. Too many responses comprised a mass of unsubstantiated numbers.</p> <p>Answers: -188 kJ mol^{-1}; -303 to -304 kJ mol^{-1} (depending on extent of intermediate rounding)</p>
	b	<p>% uncertainties to at least 1 SF, rounded or truncated</p> <p>ONE correct % uncertainty ✓</p> <p>BOTH correct % uncertainties ✓</p> <p>.....</p> <div style="border: 1px solid black; width: 100%; height: 30px; margin-bottom: 10px;"></div> <p>Calculator values:</p> <p>mass: 0.8064516129 ΔT: 0.5714285714</p>	2	<p>ALLOW error for uncertainty</p> <p>ALLOW ECF from mass and ΔT in 2(a)</p> <p>IGNORE % uncertainty of mass of solution</p> <p>ALLOW one mark for:</p> <ul style="list-style-type: none"> • 2 calculations with both $\times 2$ factors missing i.e. mass 0.3% AND ΔT 0.4% • Not converting to %s using $\times 2$ factors i.e. 0.008 AND 0.006 <p>Examiner's Comments</p> <p>Virtually all candidates realised the need to calculate percentage uncertainties, but less than half were awarded both marks. Some based their calculations on the readings rather than the difference, and others did not take into account that two readings had two uncertainties, doubling the overall uncertainty.</p> <p>Answers: mass: 0.81%; temperature change: 0.57%</p>
	c	ALLOW uncertainty OR error throughout	2	ALLOW up to 2 marks based on a single mass measurement:



		<p>Greater mass of Na₂O OR more Na₂O ✓</p> <p>For mass, ALLOW amount / moles / quantity</p> <p>larger ΔT OR reduces % uncertainty in ΔT ✓</p>		<p>one mass measurement</p> <p>OR measure mass directly ✓ <i>e.g. tare balance</i></p> <p>% uncertainty reduced by half ✓</p> <p>.....</p> <p>IGNORE</p> <ul style="list-style-type: none"> • repeat and take average • read to more figures (<i>same apparatus</i>) • increase volume (<i>reduces mass error but increases ΔT error</i>) • use a cooling curve • use a lid <p>Examiner's Comment: Many candidates did not consider reducing percentage uncertainties in the measurements (stated in the question), instead repeating readings and taking an average. Despite the question stating that the same apparatus was to be used, many suggested using a more accurate balance or thermometer, or using a lid with some form of insulation.</p> <p>The most common creditworthy answer was to increase the mass of Na₂O to reduce the percentage uncertainty in mass. The best candidates realised that an increased mass of Na₂O would produce a larger temperature change, reducing also the percentage uncertainty in ΔT. Some candidates suggested increasing the volume of the water but this would have decreased the temperature change and increased its percentage uncertainty.</p>
		Total	10	
10 4	a i	Burette readings	4	



	<p>Final (reading) /cm³ 23.15 45.95 32.45</p> <p>Initial (reading) /cm³ 0.60 23.15 10.00 ✓</p> <ul style="list-style-type: none"> • Correct titration results recorded with initial and final readings, clearly labeled <p>AND all readings recorded to two decimal places with last figure either 0 or 5</p> <p>Titres</p> <p>Titre / cm³ 22.55 22.80 22.45 ✓</p> <ul style="list-style-type: none"> • Correct subtractions to obtain final titres to 2 DP <p>Units</p> <ul style="list-style-type: none"> • Units of cm³ for initial, final and titres ✓ <p>Mean titre</p> <ul style="list-style-type: none"> • mean titre $= \frac{22.55 + 22.45}{2} = 22.50 \text{ OR } 22.5 \text{ cm}^3 \checkmark$ <p><i>i.e. using concordant (consistent) titres</i></p>	<p>Table not required</p> <p>ALLOW initial reading before final reading</p> <p>ALLOW ECF</p> <p>ALLOW units with each value ALLOW brackets for units, i.e. (cm³)</p> <p>ALLOW ECF from incorrect concordant titres</p> <p>Examiner's Comment: This question should have been four straightforward marks, but it was actually found very challenging by candidates. Most read the scales correctly but then did not present their findings clearly, often scattering unlabelled numbers around, omitting units with absence of any heading linking them to the burettes.</p> <p>0.60 was very often shown as 0.6 and 22.80 as 22.8.</p> <p>Candidates were expected to take the mean of their closest titres but a significant number took an average of all three titres instead. The mark scheme allowed for a mean titre obtained from incorrect titres.</p>
--	---	--



			Candidates need to appreciate the importance of communicating their results in a clear and comprehensive way with headings and units, and showing numerical values to the accuracy of the apparatus used.
		<p>ALLOW 3SF or more throughout IGNORE trailing zeroes, e.g. ALLOW 0.084 for 0.0840</p> <p>.....</p> $n(\text{NaOH}) = 0.0840 \times \frac{22.50}{1000} = 1.89 \times 10^{-3} \text{ (mol)} \checkmark$ $n(\text{A}) \text{ in } 250 \text{ cm}^3 = 10 \times 1.89 \times 10^{-3} = 1.89 \times 10^{-2} \text{ (mol)} \checkmark$ $M(\text{A}) = \frac{2.495}{1.89 \times 10^{-2}} = 132 \text{ (g mol}^{-1}\text{)} \checkmark$ $M(\text{alkyl group}) (= 132 - 75) = 57 \checkmark$ <p>ii R = C₄H₉ ✓</p> <p>ALLOW alkyl group in drawn structure with straight chain or branch (es) in wrong position, e.g. for R = C₄H₉, CH₃CH₂CH₂CH₂ OR (CH₃)₃C</p> <p>Structure with chiral carbon atoms identified (see * below)</p> <p style="text-align: right;">✓</p>	<p>ALLOW ECF from incorrect mean titre in 4a(i)</p> <p>e.g. From 22.60 cm³ (mean of all 3 titres in (i)), $n(\text{NaOH}) = 1.8984 \times 10^{-3} \text{ (mol)}$</p> <p>ALLOW ECF from incorrect $n(\text{NaOH})$</p> <p>ALLOW ECF from incorrect $n(\text{A})$</p> <p>ALLOW ECF from incorrect $M(\text{A}) - 75$</p> <p>ALLOW ECF for alkyl group closest to calculated $M(\text{alkyl group})$, e.g. for $M = 45$, ALLOW C₃H₇ (43)</p> <p style="text-align: center;">6</p> <p>ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous</p> <p>IGNORE poor connectivity to OH groups <i>Given in question</i></p> <p>.....</p> <p>Common error for 4 marks max <i>25.00 instead of 22.50 and scaling by × 10</i> $2.10 \times 10^{-3} \rightarrow 2.10 \times 10^{-2} \checkmark$ $\rightarrow 118.81 \checkmark \rightarrow 43.81 \checkmark \rightarrow \text{C}_3\text{H}_7 \checkmark$</p> <p><i>25.00 instead of 22.50 and scaling by</i> $\times \frac{250}{22.50}$</p> <p>$2.10 \times 10^{-3} \rightarrow 2.33 \times 10^{-2} \checkmark$ $\rightarrow 106.93 \checkmark \rightarrow 31.93 \checkmark \rightarrow \text{C}_2\text{H}_5 \checkmark$</p> <p>No structure with 2 chiral centres possible .</p> <p>Examiner's Comment:</p>



			<p>Most candidates made some headway with this problem. Candidates were expected to process their mean titre from 4(a)(i) in a conventional titration calculation to arrive at a molar mass of 132 g mol^{-1}. From there, candidates could determine a C_4H_9 alkyl group and draw the structure of compound A with two chiral carbon atoms.</p> <p>Most candidates scored some marks but processing beyond the molar mass proved to be difficult for weaker candidates. Some candidates showed a structure with a linear C_4H_9 group which contains one chiral carbon atom.</p> <p>A common error was use of 25.0 cm^3, instead of the titre, as the volume of NaOH, obtaining an initial value of $2.10 \times 10^{-3} \text{ mol}$. The mark scheme allowed processing of this value to be credited using error carried forwards. Some candidates omitted to scale their initial value by a factor of $\times 10$, obtaining a molar mass of over 1000 g mol^{-1}, e.g. 1320 instead of 132. A large range of marks was seen and the question discriminated extremely well.</p>
	b i		<p>ALLOW brackets around structure with negative charge outside, i.e.</p> <p>1</p> <p>ALLOW ring (Kekulé structure)</p> <p>Examiner's Comment: Most candidates identified the skeleton of the ligand. However, this was often drawn without the minus sign on the COO^- or with an additional minus sign on the nitrogen.</p>
	ii	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 1.61×10^{-3} award 2 marks</p> <p>$M = 418(.0) \text{ (g mol}^{-1}\text{) OR } n(\text{Cr}) = 3.85 \times 10^{-6} \text{ (mol) } \checkmark$</p> <p>Mass = $3.85 \times 10^{-6} \times 418.0 = 1.61 \times 10^{-3} \text{ g } \checkmark$</p>	<p>2</p> <p>Note: $\frac{200 \times 10^{-6}}{52.0} = 3.85 \times 10^{-6}$ (at least 3 SF)</p> <p>ALLOW ECF from incorrect M OR $n(\text{Cr})$</p> <p>ALLOW 3 SF up to calculator value correctly</p>



				<p>rounded</p> <p>For 5a(i)–(iv) IGNORE poor connectivity to SH groups</p> <p><i>Given in question</i></p> <p>Examiner's Comment: Most candidates calculated the amount of chromium correctly as 3.85×10^{-6} mol. The second mark required this value to be multiplied by the molar mass of the complex. Success here was dependent on obtaining the correct molar mass of 418 g mol^{-1}. Candidates scored better here than in 4(c)(i).</p> <p>Answer: $1.61 \times 10^{-3} \text{ g}$</p>
		Total	13	
10 5	a	i	<p><u>Electrostatic attraction</u> between positive and negative ions ✓</p>	<p>1</p> <p>ALLOW oppositely charged ions ALLOW cations and anions ALLOW '+' for positive and '-' for negative IGNORE references to metal and non-metal IGNORE references to transfer of electrons</p> <p>Examiner's Comments</p> <p>The specification describes ionic bonding as an electrostatic attraction and a small proportion of answers were missing this key phrase.</p>
		ii	<div style="text-align: center;"> </div> <p>Ba shown with either 0 or 8 electrons AND O shown with 8 electrons with 6 dots and 2 crosses (or vice versa) ✓</p> <p>Correct charges on both ions ✓</p>	<p>2</p> <p>For first mark, if eight electrons are shown around Ba, the 'extra' electrons around O must match the symbol chosen for the electrons for Ba.</p> <p>IGNORE inner shells</p> <p>Circles not required Brackets not required</p> <p>Examiner's Comments</p> <p>Covalent bonding diagrams were not</p>

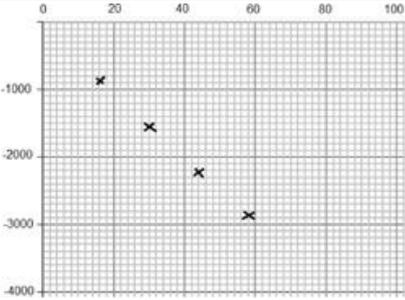
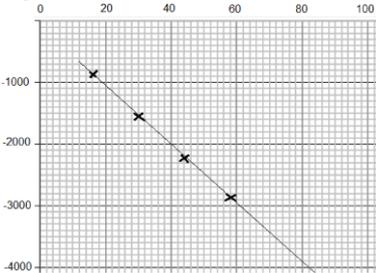


				common and this question was well answered by the vast majority of candidates.
	iii	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE</p> <p>IF answer = 5.89×10^{21} award 2 marks for calculation</p> <p><i>Moles of barium oxide</i> $n(\text{BaO}) = 1.50/153.3$ OR 9.78×10^{-3} ✓</p> <p><i>Number of barium ions</i> $(9.78 \times 10^{-3} \times 6.02 \times 10^{23}) = 5.89 \times 10^{21}$ ✓</p> <p>3 SF AND standard form required</p>	2	<p>ALLOW 0.00978 up to calculator value 0.009784735</p> <p>ALLOW ECF from incorrect moles of BaO Common incorrect answers are shown below</p> <p>IF 137.3 is used for the molar mass ALLOW 1 mark total for 6.58×10^{21} (0.010924981 mol) OR 6.56×10^{21} (0.0109 mol)</p> <p>IF 153 is used for the molar mass ALLOW 1 mark total for 5.90×10^{21}</p> <p>Examiner's Comments</p> <p>Use of the relative mass of barium to calculate moles of barium oxide was a common error but these candidates were usually able to pick up one mark for correctly multiplying their moles by the Avogadro constant. Some candidates correctly calculated moles but then divided by two thus losing the final mark.</p>
	b i	<p>Barium chloride does not conduct electricity when solid AND because it has ions which are fixed (in position / in lattice) ✓</p> <p>Barium chloride conducts when in aqueous solution AND because it has mobile ions ✓</p>	2	<p>IGNORE use of 'free' instead of 'mobile' ALLOW ions are not free to move ALLOW ions are held (in position / in lattice) ALLOW ions are not mobile IGNORE charge carriers DO NOT ALLOW electrons moving ALLOW one mark for comparison that does not identify (s) and (aq).</p> <p>Examiner's Comments</p> <p>Many precise answers gained full marks by describing the fixed position of ions in a lattice and the mobility of ions in aqueous solution. Delocalised or free electrons were occasionally mentioned. Vague answers often used the terms 'free' instead of mobile,</p>

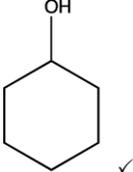


					'charge carrier' instead of ion and 'carry a charge' instead of conduct electricity.
		ii	Test for sulfate / SO_4^{2-} ✓ <u>White</u> precipitate forms (when barium chloride solution is mixed with a solution containing sulfate ions) ✓	2	IGNORE hydrochloric acid ALLOW white solid IGNORE cloudy DO NOT ALLOW test result linked to incorrect anion Examiner's Comments There was some confusion with the displacement reactions of halogens, the test for halide ions and the use of silver nitrate but the majority of students could recall the use of aqueous barium chloride to test for sulfate ions. Occasionally candidates described the use of dilute hydrochloric acid to remove carbonate ions from solution before their creditworthy description of the sulfate test.
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 2 award 2 marks $M(\text{BaCl}_2) = ((137.3 + (35.5 \times 2)) = \underline{208.3} \text{ (g mol}^{-1}\text{)})$ ✓ $244.3 - 208.3 = 36$ AND $36/18 = 2$ ✓	2	ALLOW 208 (g mol ⁻¹) ALLOW ECF for incorrectly calculated molar mass provided the final answer is rounded to nearest whole number Examiner's Comments Very well answered, the majority of candidates scored full marks for this simple calculation.
			Total	11	
10 6		i	Value for butane plotted accurately on the graph ✓	3	relative molecular mass = 58 $\Delta_c H^\ominus = -2877 \text{ kJ mol}^{-1}$



			 <p>Check accuracy:</p> <ul style="list-style-type: none"> • There must be a visible point • Vertically: touching the 58 line • Horizontally: between 2800 and 2900 <p>Examiner's Comments</p> <p>Most, but not all, candidates were able to plot the value for butane accurately on the graph.</p>
ii		<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF energy released = 87.5 (minimum) to 90 (maximum) AND line is extrapolated to 72 (molar mass) award 3 marks IF energy released <87.5 OR > 90.0 check the estimated value of $\Delta_c H^\ominus$ from the graph</p> <p><i>Estimation of $\Delta_c H^\ominus$</i> extrapolated (straight) line of best fit (see graph) AND correctly estimated value $\Delta_c H^\ominus$ from graph ✓</p> <p><i>Calculation of energy released</i> $n(\text{C}_5\text{H}_{12}) = 0.0250 \text{ mol}$ ✓ <i>energy released</i> $= 0.0250 \times$ correctly estimated value of $\Delta_c H^\ominus$ ✓</p>	<p>relative molecular mass = 72</p> <p>$\Delta_c H^\ominus = -3509 \text{ kJ mol}^{-1}$</p>  <p>Expected value within range: (-)3500 to (-)3600 (kJ mol^{-1})</p> <p>moles = $1.80/72.0$</p> <p>IGNORE sign</p> <p>ALLOW ECF from incorrectly calculated moles of pentane OR incorrectly estimated $\Delta_c H^\ominus$</p> <p>Examiner's Comment:</p> <p>A good proportion of candidates scored full marks for their estimate but some did not</p>



				extrapolate the line on the graph and many did not calculate the amount of pentane. This restricted their answer to an estimate of the energy released by one mole of pentane and this could only score one mark.
		Total	4	
10 7	i	 <p>Acid (catalyst) AND heat ✓</p>	2	<p>ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous</p> <p>ALLOW (heat under) reflux ALLOW H₃PO₄ OR H₂SO₄ OR H⁺ DO NOT ALLOW other named acids IGNORE concentration / pressure IGNORE water / steam</p> <p>Examiner's Comments</p> <p>Candidates who were able to give the structure of the intermediate were not always able to state the conditions for the elimination of water from an alcohol. The presence of an acid catalyst and heat are stated in the specification. Some candidates confused this reaction with addition reactions of alkenes suggesting that a Ni catalyst or the presence of steam is required.</p>
	ii	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 44.4(%) award all 3 marks for calculation</p> <p><i>Amount cyclohexene (m / M)</i> = 1.23/82 OR 0.0150 mol ✓</p> <p><i>Amount of bromocyclohexane (m / M)</i> = 5.50/162.9 OR 0.0338 mol ✓</p> <p>% yield = (0.0150/0.0338) × 100 = 44.4(%) ✓</p> <p>Final answer must be to 3 significant figures</p>	3	<p>If there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW 3 SF: 0.0338 up to calculator value of 0.033763044 correctly rounded</p> <p>Common ECFs (2 marks)</p> <ul style="list-style-type: none"> • Incorrect M_r → incorrect moles of cyclohexene • Incorrect M_r → incorrect moles of 2-bromocyclohexane



				<p>e.g. ALLOW two marks for use of incorrect mass of bromocyclohexane with other calculations correct e.g. $(5.50/163) = 0.033742331 \rightarrow 44.5\%$</p> <p>ALLOW calculation in mass <i>Theoretical mass yield:</i> $m(\text{C}_6\text{H}_{10}) = 0.0338 \times 82 = 2.77 \text{ g}$ $\% \text{ yield} = (1.23/2.77) \times 100 = 44.4\%$</p> <p>Examiner's Comment:</p> <p>Although some candidates simply calculated $1.23/5.50$, most followed an effective strategy for the calculation of percentage yield. Many gained full marks but a large number of candidates relied on the application of error carried forward when they made one or more careless errors during the calculation of molar mass and / or moles. Intermediate answers were sometimes rounded to 2 significant figures and marks were lost by candidates who presented their final answer to 2 or 4 significant figures.</p>
		Total	5	
10 8		<p>Observations linked to anion identifications</p> <p>Bubbles/effervescence/fizzing/gas AND carbonate ✓</p> <p>(white OR precipitate) AND sulfate ✓</p> <p>Use of molar mass in reasoning</p> <p>Molar mass used ONCE with carbonate OR sulfate ✓</p>	5	<p>FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED</p> <p>For bubbles, ALLOW carbon dioxide/CO_2 BUT DO NOT ALLOW hydrogen/H_2</p> <p>For carbonate, ALLOW CO_3 For sulfate, ALLOW SO_4</p> <p>e.g. Carbonate: $140 - (12 + 48)$; $140 - 60$ Sulfate: $140 - (32.1 + 64)$; $140 - 96.1$ $\text{K}_2\text{CO}_3 = 138.1$ $\text{Na}_2\text{SO}_4 = 142.1$</p> <p>ALLOW ONE of the two identification marks for:</p> <ul style="list-style-type: none"> Correct names: B potassium carbonate AND C sodium sulfate



		<p>Identification</p> <p>B: K_2CO_3 ✓</p> <p>C: Na_2SO_4 ✓</p>		<ul style="list-style-type: none"> Incorrect formulae i.e. B KCO_3 AND C $NaSO_4$ <i>Communicates the same as names</i> <p>Examiner's Comments This was a challenging question that discriminated extremely well. The more able candidates derived the anions from the two chemical tests and identified the cations using the molar masses of the salt and the anions.</p> <p>Weak candidates seemed to have little idea on how to approach such a question and they often achieved no credit.</p> <p>It was disappointing that many candidates were unable to identify a carbonate and sulfate from their chemical tests. Common errors included incorrectly identifying the gas with dilute acid as hydrogen, and identifying the white precipitate with barium ions as characteristic of a chloride.</p> <p>Candidates who used the provided molar mass of 140 usually went on to show that the cations contributed masses of approximately 80 for the carbonate and 44 for the sulfate. Candidates then needed to divide each value by 2 to obtain formulae of K_2CO_3 and Na_2SO_4. Many did not divide by 2 and instead concluded that the compounds were $RbCO_3$, KSO_4 or $CaSO_4$.</p> <p>Strangely, some candidates thought they were identifying Group 1 metals and not salts.</p>
		Total	5	
10 9	i	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $2.21 \text{ (mol dm}^{-3}\text{)}$ award 4 marks</p> <p>-----</p> <p>TITRATION</p>	4	<p>FULL ANNOTATIONS MUST BE USED -----</p> <p>ALLOW 3 SF or more correctly rounded throughout Apply ECF where appropriate</p> <p>ALLOW ECF from $n(\text{Ba}(\text{OH})_2)$ -----</p> <p>ALTERNATIVE APPROACHES FOR M3 AND M4:</p>



		<p>M1 $n(\text{Ba}(\text{OH})_2)$ in 25.0 cm³ = = 1.125×10^{-3} (mol) ✓</p> <p>M2 $n(\text{CH}_3\text{COOH})$ in 25.45 cm³ diluted vinegar = $2 \times 1.125 \times 10^{-3}$ = 2.25×10^{-3} (mol) ✓</p> <hr/> <p>SCALING ALLOW ECF from $n(\text{CH}_3\text{COOH})$</p> <p>M3 $[\text{CH}_3\text{COOH}]$ in diluted vinegar = $\frac{2.25 \times 10^{-3} \times 1000}{25.45}$ = 0.0884 (mol dm⁻³) ✓ Calculator: 0.0884086</p> <p>M4 $[\text{CH}_3\text{COOH}]$ in original vinegar = $\frac{0.0884 \times 250}{10.0}$ = 2.21 (mol dm⁻³) ✓</p>		<p>M3 $n(\text{CH}_3\text{COOH})$ in 25.45 cm³ original vinegar = $\frac{2.25 \times 10^{-3} \times 250}{10.0}$ = 0.05625 (mol) ✓</p> <p>M4 $[\text{CH}_3\text{COOH}]$ in original vinegar = $\frac{0.05625 \times 1000}{25.45}$ = 2.21 (mol dm⁻³) ✓</p> <hr/> <p>M3 $n(\text{CH}_3\text{COOH})$ in 250 cm³ diluted vinegar = $\frac{2.25 \times 10^{-3} \times 250}{25.45}$ = 0.0221 (mol) ✓</p> <p>M4 $[\text{CH}_3\text{COOH}]$ in original vinegar = $0.0221 \times \frac{1000}{250} \times \frac{250}{10.0}$ = 2.21 (mol dm⁻³) ✓</p> <p>Examiner's Comments This was a challenging unstructured titration calculation for AS level. Very able candidates rose to the challenge to secure all four marks. Many obtained the correct concentration of 0.0884 mol dm⁻³ for the diluted vinegar, but did not then use the dilution factor to convert this to the concentration of the original vinegar. Weaker candidates often obtained two relatively straightforward marks for the amounts of barium hydroxide and ethanoic acid used in the titration. Some otherwise good responses were not awarded full marks by excessive intermediate rounding, e.g. 0.0884 to 0.088, which then gave a rounding error in the final answer. Answer: 2.21 mol dm⁻³</p>
	ii	<p>Assumption:</p> <p>Vinegar contains (ethanoic acid and) no other acids ✓</p> <p>Prediction:</p> <p>Experimental result is greater than conc of CH₃COOH OR conc of CH₃COOH is less than experimental result ✓</p>	2	<p>For credit, the response must refer to other acids IGNORE impurities, solution is pure, etc</p> <p>ONLY award the 'prediction' mark if 'assumption' mark is correct</p> <p>Examiner's Comments This question proved to be the most difficult on the paper. Very few candidates realised the key assumption that ethanoic acid was the only acid in the vinegar. Most candidates responded with mistakes made in the procedure such as overshooting the end point, the meniscus not being read properly, faulty apparatus, etc.</p>
		Total	6	
110		FIRST check the molar mass on answer line	5	FULL ANNOTATIONS MUST BE USED -----



MUST be derived from $pV = nRT$,
Award 4 marks for calculation for:

- answer = 70
- OR answer that rounds to 69.9 OR 70.0

Rearranging ideal gas equation to make n subject

$$n = \frac{pV}{RT} \checkmark$$

Substituting all values including conversion to Pa and m^3

$$n = \frac{(101 \times 10^3) \times (82.5 \times 10^{-6})}{8.314 \times 373} \checkmark$$

$$n = \underset{\text{unrounded}}{2.68693073 \times 10^{-3}} \rightarrow \underset{\text{rounded to 3 SF}}{2.69 \times 10^{-3}} \text{ (mol)} \checkmark$$

Calculation of molar mass, M

$$M = \frac{m}{n} = \frac{0.1881}{2.68693073 \times 10^{-3}} = 70(.0) \text{ (g mol}^{-1}\text{)}$$

$$\rightarrow \frac{0.1881}{2.69 \times 10^{-3}} = 69.9 \text{ (g mol}^{-1}\text{)} \checkmark$$

Molecular formula of **D**
 $C_5H_{10} \checkmark$

IF candidate has failed to derive suitable value of n , **ALLOW** value of M from 0.1881 **AND** 24000 with alkene closest to calculated value for last 2 marks
See Guidance column.

If there is an alternative answer, check to see if there is any ECF credit possible using working below

1st mark may be implicit by direct substitution of correct values below into rearranged equation.

ONLY award this mark if n has been derived from correct rearranged ideal gas equation **ALLOW 3 SF** up to calculator value, correctly rounded

NOTE: ALLOW 69.9 \rightarrow 70.0 **AND** 70 (2 SF)
Calculator from unrounded: 70.00552634

ALLOW any unambiguous structure
ALLOW ECF provided that formula given is an alkene and matches M calculated from 0.1881 **AND** $pV = nRT$

$$M = \frac{0.1881}{82.5/24000} \text{ OR } \frac{0.1881}{3.4375 \times 10^{-3}}$$

$$= 54.72 \text{ OR } 54.7 \text{ OR } 55 \checkmark$$

ALLOW 54.68 from use of 3.44×10^{-3}

From **54.72**, **ONLY ALLOW** = $C_4H_8 \checkmark$

Examiner's Comments

Most candidates realised the need to use the ideal gas equation. The equation was usually rearranged correctly, with substituted values for p , V , R and T being added. Pressure and volume were not always converted correctly into Pa and m^3 , creating problems for subsequent parts. Many candidates attempted to convert from cm^3 to m^3 by multiplying by 10^{-3} rather than 10^{-6} .

Candidates usually obtained a value for n , although those who had struggled with unit



				<p>conversion obtained values that differed by powers of 10. Finally, candidates needed to derive the molar mass using their value of n and the mass of the alkene. Some candidates over-rounded their value of n, introducing an error in calculating the molar mass.</p> <p>Surprisingly, an appreciable number of candidates wrote their value of n on the answer line rather than the molar mass indicated by the answer prompt. This suggested that some candidates do not understand the term molar mass.</p> <p>Candidates who had obtained a molar mass of 70.0 usually determined that the alkene had the formula C_5H_{10}. Answer: 70.0 g mol^{-1}</p>
		Total	5	
11 1	a	$n(\text{H}_2\text{O}_2) = 2.30 \times \frac{25.0}{1000} \text{ OR } = 0.0575 \text{ (mol)} \checkmark$ $\text{vol O}_2 = \frac{0.0575}{2} \times 24000 = 690 \text{ cm}^3 \checkmark$ <p>Collect in $1000 \text{ cm}^3/1 \text{ dm}^3$ measuring cylinder \checkmark</p>	3	<p>ALLOW $0.69(0) \text{ dm}^3$ 2nd mark subsumes 1st mark</p> <p>ALLOW $1000 \text{ cm}^3/1 \text{ dm}^3$ syringe Needs a name of actual apparatus, not just 'container' 'measuring cylinder' without volume is insufficient</p> <p>DO NOT ALLOW burette For other possible apparatus, contact Team Leader</p> <p>ALLOW volumes from $700\text{--}1000 \text{ cm}^3$ but should be realistic apparatus, e.g. 700, 750, 800, 850, 900, 950.</p> <p>Examiner's Comments The majority of candidates were able to score the two marks for determining the volume of oxygen to be 690 cm^3 (or 0.690 dm^3). Only a very small proportion of candidates were able to suggest a suitably sized piece of apparatus.</p>
	b	Measure mass (loss) \checkmark	1	<p>ALLOW weight for mass</p> <p>ALLOW take samples and titrate (remaining</p>



				H ₂ O ₂)
				<p>Examiner's Comments The idea of measuring mass loss (over time) was frequently given as a correct response. The idea of titrating samples to determine the concentration of hydrogen peroxide during the course of the reaction was occasionally seen and given credit.</p>
		Total	4	
11 2	i	<p>[CH₃COO⁻] $n(\text{CH}_3\text{COONa}) = \frac{9.08}{82.0}$ OR 0.111 ✓ (Calc: 0.11073170) $[\text{CH}_3\text{COO}^-] = \frac{9.08}{82.0} \times \frac{1000}{250} = 0.443 \text{ (mol dm}^{-3}\text{)}$ OR $n(\text{CH}_3\text{COOH}) = 0.800 \times \frac{250}{1000} = 0.200 \text{ (mol) ✓}$</p> <p>[H⁺] $[\text{H}^+] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$ OR $K_a \times \frac{n(\text{CH}_3\text{COOH})}{n(\text{CH}_3\text{COO}^-)}$ = $1.75 \times 10^{-5} \times \frac{0.800}{0.443}$ OR $1.75 \times 10^{-5} \times \frac{0.200}{0.111}$ ✓ = $3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{) ✓}$</p> <p>pH (must come from <i>calculated</i> [H⁺]) pH = $-\log(3.16 \times 10^{-5}) = 4.50$ ✓</p> <p>..... LAST 3 marks are NOT available using</p> <ul style="list-style-type: none"> • K_a square root approach (weak acid pH) • $K_w/10^{-14}$ approach (strong base pH) <p>..... Henderson-Hasselbalch (HH) alternative pKa = $-\log 1.75 \times 10^{-5} = 4.757$ (or 4.756961951..)</p>	5	<p>ALLOW 2 sig fig ALLOW use of HA and A⁻</p> <p>Mark by ECF</p> <p>.....</p> <p>Alternative method (If both methods are attempted, mark the method which produces the higher mark) [H⁺] $[\text{H}^+] = 10^{-\text{pH}} = 10^{-4.50}$ = $3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{) ✓}$</p> <p>[CH₃COO⁻]</p> $[\text{CH}_3\text{COO}^-] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{H}^+]}$ OR $1.75 \times 10^{-5} \times \frac{0.800}{3.16 \times 10^{-5}}$ ✓ = $0.443 \text{ (mol dm}^{-3}\text{) ✓}$ <p>mass of CH₃COONa</p> $\text{mass CH}_3\text{COONa} = 0.443 \times \frac{250}{1000}$ OR 0.111 ✓ $0.111 \times 82.0 = 9.08 \text{ (g) ✓}$ <p>.....</p> <p>Common errors</p> <p>4.64 Use of $M(\text{CH}_3\text{COONa}) = 60$ 4 marks 2.40 Use of K_a of FCH₂COOH 4 marks</p> <p>Examiner's Comments</p>



		$\text{pH} = \text{p}K_a + \log \frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$ <p>OR $\text{pH} = \text{p}K_a - \log \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$</p> $\text{OR } \text{p}K_a + \log \frac{0.443}{0.800} \quad \text{OR } = \text{p}K_a - \log \frac{0.800}{0.443} \checkmark$ $= \text{p}K_a - 0.257 \checkmark$ $= 4.757 - 0.257 = 4.50 \checkmark$		<p>This question caused difficulty for all but the more able. For many weaker candidates getting beyond a concentration of CH_3COONa was a problem. Once again, candidates should be advised to show every step in their calculation. This would allow method marks to be applied in the absence of a correct final answer.</p>
	ii	<p>pH is the same/constant \checkmark</p> <p>ratio/proportion $[\text{HA}]/[\text{A}^-]$ is the same \checkmark</p>	2	<p>M2 is dependent upon M1</p> <p>ALLOW Change in $[\text{HA}]$ and $[\text{A}^-]$ is proportional</p> <p>Examiner's Comments Only the very able were able to explain that the ratio of concentrations of acid and salt would remain constant and as K_a is constant, $[\text{H}^+]$ and therefore pH would remain constant.</p>
		Total	7	
11 3		<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) A comprehensive conclusion using all data to obtain correct formulae for A, B, C and D AND optical isomers shown</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured with use of 3D structures for both optical isomers of C, use of wedges and bonding to N. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Reaches a sound conclusion for the formula of B AND obtains the correct formula of the hydrated complex A OR a 3D diagram of one optical isomer of cation C</p> <p><i>There is a line of reasoning and supported</i></p>	6	<p>Indicative scientific points may include:</p> <p>1. Formula of anhydrous complex B $\text{NiC}_6\text{N}_6\text{H}_{24}\text{Cl}_2$</p> <p><i>Example of working</i></p> $= \frac{18.95}{58.7} : \frac{23.25}{12.0} : \frac{27.12}{14.0} : \frac{7.75}{1.00} : \frac{22.93}{35.5}$ <p>There may be other methods</p> <p>2. Formula of hydrated complex A $\text{NiC}_6\text{N}_6\text{H}_{24}\text{Cl}_2 \cdot 2\text{H}_2\text{O}$ OR $\text{NiC}_6\text{N}_6\text{H}_{24}\text{Cl}_2(\text{H}_2\text{O})_2$</p> <p><i>Example of working</i></p> $n(\text{anhydrous salt}) = \frac{7.433}{309.7} = 0.02400 \text{ (mol)}$ $n(\text{H}_2\text{O}) = \frac{0.864}{18.0} = 0.04800 \text{ (mol)} \checkmark$ <p>There may be other methods</p> <p>3. Formula of cation C $[\text{NiC}_6\text{N}_6\text{H}_{24}]^{2+}$ OR $[\text{Ni}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+}$ <i>(could be in structures)</i></p>



by some evidence. Calculations are clear and can be followed to obtain correct conclusions. 3D diagram, if present, should use wedges mostly correctly.

Formula of **A** to show water separately or formula of **C** to show ligands separately, as appropriate.

Level 1 (1–2 marks)

Reaches a simple conclusion to obtain the correct formula of anhydrous complex **B** OR shows that **A** contains $2\text{H}_2\text{O}$

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. Attempts more than one part of the problem.

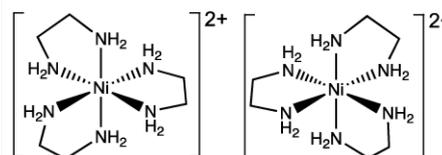
0 marks No response or no response worthy of credit.

$2+$ charge can be shown on cation **OR** optical isomers (i.e. seen somewhere)

- **Bidentate ligand D**

$\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ or displayed so that structure is clearly unambiguous.

- **Optical isomers**

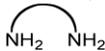


Accuracy of structures

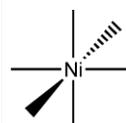
Bonding shown from Ni to N of $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$

ALLOW $\text{CH}_3\text{CH}(\text{NH}_2)_2$ for ligand

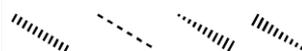
For $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ in optical isomers,

ALLOW C–C without Hs and 

Each structure to contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge':



Bond into paper can be shown as:



Examiner's Comments

This was the second extended response question. Most candidates were able to make



				<p>a start on this response and found the formula of B. A significant number of candidates assumed the bidentate ligand D to be $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ and worked backwards to identify C. Having identified C, the drawing of optical isomers proved relatively straightforward.</p> <p>Many strong candidates omitted to determine the formula of A or realised quite late on within their extended response that this was required.</p>
		Total	6	
11 4	i	$\text{P}_4 + 6\text{Br}_2 \rightarrow 4\text{PBr}_3$	1	ignore state symbols
	ii	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 3.01×10^{21} award 3 marks</p> <p>$M_r(\text{PBr}_3) = 270.7 \text{ (g mol}^{-1}\text{)} \text{ (1)}$</p> <p>$n(\text{PBr}_3) = 1.3535 / 270.7 = 5.000 \times 10^{-3} \text{ mol (1)}$</p> <p>number of molecules = $5.000 \times 10^{-3} \times 6.02 \times 10^{23} = 3.01 \times 10^{21} \text{ molecules (1)}$</p>	3	<p>If there is an alternative answer, check to see if there is any ecf credit possible using working below.</p> <p>allow in working shown as $28.1 + 35.5 \times 4$</p> <p>allow ecf from incorrect molar mass of PBr_3 allow 0.005(00) (mol) for two marks</p> <p>allow ecf for incorrect amount of PBr_3 allow calculator value or rounding to 3 significant figures or more but ignore 'trailing' zeroes, e.g. 0.200 allowed as 0.2</p> <p>do not allow any marks for: $1.3535 \times 6.02 \times 10^{23} = 8.15 \times 10^{23}$</p>
	iii	<p>Pyramidal (1)</p> <p>(because there are) 3 bonded pairs and 1 lone pair (around the central phosphorus atom) (1)</p> <p>and electron pairs repel each other as far apart as possible so will take on a tetrahedral arrangement (giving a pyramidal shape overall) (1)</p>	3	
		Total	7	
11 5		<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 76.5 (%) award 3 marks</p>	3	If there is an alternative answer, check to see if there is any ECF credit possible using working below



		$n(\text{NH}_3) = (1 \times 10^6) / 17 = 5.88 \times 10^4$ (58824) (mol) AND <i>Theoretical yield:</i> $n(\text{NH}_2\text{CONH}_2) = 5.88 \times 10^4 / 2 = 2.94 \times 10^4$ (29412) (mol) (1) <i>Actual yield:</i> $n(\text{NH}_2\text{CONH}_2) = 1.35 \times 10^6 / 60 = 2.25 \times 10^4$ (22500) (mol) (1) $\% \text{ yield} = (2.94 \times 10^4 / 2.25 \times 10^4) \times 100\% = 76.5(\%)$ (1)		allow up to full calculator display For 2 nd and 3 rd marks, allow calculation in mass. <i>Theoretical mass yield:</i> $m(\text{NH}_2\text{CONH}_2) = 60 \times 5.88 \times 10^4 / 2 = 1.764$ tonne $\% \text{ yield} = (1.35 / 1.764) \times 100 = 76.5\%$ allow 76% (2 sig figs) up to calculator answer correctly rounded from previous values allow ecf from calculated actual and theoretical yields
		Total	3	
11 6		(Minimum) $n(\text{pentan-2-ol})$ required = $0.1 \times 88 = 8.8$ g (1) React the alcohol with a mixture of NaBr AND H_2SO_4 AND warm (to distil off the product) (1)	2	allow HBr
		Total	2	
11 7	a i	Initial reading = 0.60 (cm^3) Final reading = 22.80 (cm^3) Titre = 22.20 cm^3 Initial and final values recorded to two decimal places AND titre recorded to the nearest 0.05 cm^3 with correct units	1	
	ii	Suggests repeating the titration to obtain consistent / concordant results (those that agree to within 0.1 cm^3) AND calculating the mean titre	1	
	b i	$n(\text{HCl}) = (0.100)(\text{answer to (c)(i)}/1000) = 0.00222$ (mol) (1)	2	allow ecf from (b)(i)



		$n(\text{M}_2\text{CO}_3) = 0.00222/2 = 0.00111 \text{ (mol) (1)}$														
	ii	$n(\text{M}_2\text{CO}_3) \text{ in total} = 0.00111 \times 10 = 0.0111 \text{ mol (1)}$ Molar mass = $1.58/0.0111 = 142.3 \text{ g mol}^{-1} \text{ (1)}$ Mass of M = $(142.3 - 60)/2 = 41.15 \text{ (= K) (1)}$ $\text{K}_2\text{CO}_3 \text{ (1)}$	4	Note: molar mass is between K_2CO_3 (138.2) and SrCO_3 (147.6); only possible match for a Group 1 carbonate is K_2CO_3 .												
		Total	8													
11 8	a i	<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <tbody> <tr> <td style="padding: 2px;">Final reading/ cm³</td> <td style="padding: 2px;">27.30</td> <td style="padding: 2px;">27.00</td> <td style="padding: 2px;">27.75</td> </tr> <tr> <td style="padding: 2px;">Initial reading/ cm³</td> <td style="padding: 2px;">0.45</td> <td style="padding: 2px;">0.60</td> <td style="padding: 2px;">1.25</td> </tr> <tr> <td style="padding: 2px;">Titre/cm³</td> <td style="padding: 2px;">26.85</td> <td style="padding: 2px;">26.40</td> <td style="padding: 2px;">26.50</td> </tr> </tbody> </table> <p>Initial and final readings All burette readings (×6) correct ✓</p> <p>Titres recorded to two decimal places with the last figure either 0 or 5 Correct subtractions to obtain final titre values ✓</p> <p>Mean titre calculated from concordant results Correct mean titre = 26.45 (cm³) ✓</p> <p>Mean titre recorded to accuracy of burette Final answer recorded to two decimal places with the last figure either 0 or 5 ✓</p>	Final reading/ cm ³	27.30	27.00	27.75	Initial reading/ cm ³	0.45	0.60	1.25	Titre/cm ³	26.85	26.40	26.50	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>ALLOW missing zeroes for burette readings i.e. 0.6 for 0.60 27 OR 27.0 for 27.00</p> <p>ALLOW ECF from incorrect burette readings</p> <p>IF MEAN IS CALCULATED FROM ECF, IT MUST BE FROM CLOSEST TITRES</p> <p>ALLOW ecf from incorrect mean DO NOT ALLOW 26.5 cm³ <i>Question asks for nearest 0.05 cm³</i></p> <p>Examiner's Comments</p> <p>Most candidates were able to accurately record the burette readings and made the correct subtractions. Despite the examination question requesting the mean titre to be recorded to the accuracy of the burette, many candidates did not do this. A common error was taking a mean of all three readings instead of only the concordant results; this led the candidates to give an answer of 26.58 which lost them 2 marks.</p>
Final reading/ cm ³	27.30	27.00	27.75													
Initial reading/ cm ³	0.45	0.60	1.25													
Titre/cm ³	26.85	26.40	26.50													
	ii	$\frac{2 \times 0.05}{26.85} \times 100 = 0.37(2) \text{ (%) } \checkmark$	1	<p>ALLOW 0.4 up to full calculation display of 0.372439478</p> <p>ALLOW ECF FOR CORRECT CALCULATION FROM 1 (c) (i) OR USE OF</p>												



				<p>ANY TITRE</p> <p><u>Examiner's Comments</u></p> <p>A good attempt by many candidates but some did not know how to calculate this or did not multiply by 2.</p>
	iii	Use a (250 cm ³) volumetric flask (instead of a beaker)✓	1	<p>IGNORE graduated flask</p> <p><u>Examiner's Comments</u></p> <p>Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.</p>
	b i	<p>FIRST CHECK ANSWER ON ANSWER LINE</p> <p>If answer = 118 (g mol⁻¹) award 4 marks If answer = 108 (g mol⁻¹) award 3 marks</p> <hr/> <p>$n(\text{NaOH})$ $= 0.112 \times \frac{25.0}{1000} = 0.00280 \text{ (mol) } \checkmark$</p> <p>$n(\text{A})$ in 25.0 cm³ $= \frac{0.00280}{2} = 0.00140 \text{ (mol) } \checkmark$</p> <p>$n(\text{A})$ in 250 cm³ $= 0.00140 \times \frac{250.0}{27.30} = 0.0128 \text{ (mol) } \checkmark$</p> <p>Molar mass, $M(\text{A})$ to nearest whole number. $= \frac{1.513}{0.0128} = 118 \text{ (g mol}^{-1}\text{) } \checkmark$</p>	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>Throughout: IGNORE trailing zeroes in intermediate working, e.g. For $n(\text{NaOH})$ ALLOW 0.0028 for 0.00280</p> <p>ALLOW ECF from incorrect $n(\text{NaOH})$</p> <p>ALLOW ECF from incorrect $n(\text{A})$ OR $n(\text{NaOH})$ ALLOW 3 sig fig up to full calculator display correctly rounded (0.012820512)</p> <p>ALLOW ECF from incorrect $n(\text{NaOH})$</p> <hr/> <p>Possible ECFs for 3 marks $1.513 \div (0.00140 \times 250/25) = 108$ $1.513 \div 0.00140 = \mathbf{1081}$</p> <p>No $\div 2$ for $n(\text{A})$</p> <ul style="list-style-type: none"> Molar mass A = 59 (g mol⁻¹) Using mean titre of 26.45 cm³ from 1c(i) Molar mass A = 114 (g mol⁻¹) Using 27.3×0.112 in M1 and then 25.0 in M3 Molar mass A = 99 (g mol⁻¹)



				<u>Examiner's Comments</u>
				Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.
		ii	Structure of dicarboxylic acid HOOCCH ₂ CH ₂ COOH OR HOOCCH(CH ₃)COOH ✓ STRUCTURE MUST MATCH M_r from answer to 1 d) i) (within 10 AMU)	1 ALLOW correct structural OR skeletal OR displayed formulae OR a combination ALLOW incorrect connectivity e.g -HO ALLOW ECF from incorrect molar mass in (d)(i) but only if 2 × COOH possible and M _r is a close match to (d) (i) within 10 AMU <u>Examiner's Comments</u> Most candidates that obtained a sensible value for the previous question managed to draw a creditable structure. Allowing error carried forward meant that feasibly derived structures could be credited a mark.
		Total		11
11 9		i	(1s ²) 2s ² 2p ⁶ 3s ² 3p ⁶ 3d ¹⁰ 4s ² 4p ⁴ ✓ Look carefully at (1s ²) 2s ² 2p ⁶ 3s ² 3p ⁶ – there may be a mistake	1 ALLOW subscripts ALLOW in any order i.e. 3d ¹⁰ after 4s ² or after 4p ⁴ ALLOW upper case D, etc and subscripts, e.g.3S ₂ 3P ⁶ DO NOT ALLOW [Ar] as shorthand for 1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ <u>Examiner's Comments</u> Most candidates answered this correctly. The most common error seen was 4p ⁶ instead of 4p ⁴
		ii	Gas B H ₂ Se / Hydrogen selenide / Selenium hydride ✓ Equation Na ₂ Se + 2HCl → 2NaCl + H ₂ Se All formulae and balancing ✓	2 ALLOW SeH ₂ ALLOW correct multiples IGNORE STATE SYMBOLS



				<p>DO NOT ALLOW H₂S for gas B BUT ALLOW ECF from H₂S for equation: $\text{Na}_2\text{S} + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{S}$</p> <p>Examiner's Comments</p> <p>The majority of candidates obtained 1 or 2 marks on this question. The most common errors seen were identifying the gas as H₂S or incorrect balancing.</p>
		Total	3	
12 0	i	<p>Reactants, products and E_a Reactants on LHS $4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g})$ AND Products on RHS $4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$ AND Activation energy correctly labelled / E_a ✓</p> <p>ΔH ΔH labelled with product below reactant AND Arrow downwards ✓</p>	2	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>IGNORE state symbols</p> <p>ALLOW 1 mark for a correctly labelled endothermic diagram</p> <p>ALLOW no arrowhead or arrowheads at both end of E_a line.</p> <p>E_a E_a line must reach maximum (or near to maximum) on curve</p> <p>For E_a, ALLOW AE OR A_E DO NOT ALLOW $-\Delta H$ DO NOT ALLOW double headed arrow on ΔH</p> <p>ΔH ALLOW ΔH arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line.</p> <p>ALLOW -905 for ΔH</p> <p>Examiner's Comments</p> <p>Most candidates were able to gain the first mark, but many lost the second mark by putting a double headed arrow or $-\Delta H$.</p>
	ii	<p>FIRST CHECK ON ANSWER LINE If answer = 6.79×10^7 (kJ) award 4 marks If answer = 2.72×10^8 (kJ) award 3 marks (no $\div 4$)</p>	4	<p>IGNORE (-) SIGN</p> <p>Throughout: IGNORE trailing zeroes in intermediate working, e.g. For $n(\text{NH}_3)$ ALLOW 3×10^5 for 3.00×10^5</p>

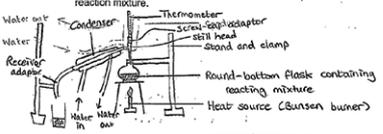


		<p>$n(\text{NH}_3)$ $= \frac{5.1 \times 10^6}{17} = 3.00 \times 10^5 \text{ (mol)} \checkmark$</p> <p>Stoichiometry and ΔH</p> <p>1 mol NH_3 releases $\frac{905}{4}$ OR 226.25 (kJ) \checkmark</p> <p>Energy released</p> <p>$(3.00 \times 10^5) \times \frac{905}{4}$ OR 67875000 (kJ) \checkmark</p> <p>Final answer to 3SF AND standard form $= 6.79 \times 10^7 \text{ (kJ)} \checkmark$ <i>standard form AND 3 SF required</i></p>		<p>_____</p> <p>_____</p> <p>ALLOW ECF from incorrect $n(\text{NH}_3)$ OR 905/4</p> <p>ALLOW 3 SF up to calc value correctly rounded. Value will depend on intermediate rounding</p> <p>Common Errors</p> <p>1.09×10^9 ($\times 4$ instead of $\div 4$) 3 marks 2.72×10^8 (no $\div 4$) 3 marks 6.79×10^1 (no tonnes \rightarrow g) 3 marks</p> <p><u>Examiner's Comments</u></p> <p>Most candidates were able to convert from tonnes to moles and then went on to complete the majority of the calculation steps. Many omitted to divide by 4 and were credited 3 marks. Some candidates lost marks by not stating the answer to standard form or quoted their answer to more than 3 significant figures. A number of candidates attempted to use $Q = mc\Delta T$ and did not get very far in the calculation.</p>
		Total	6	
12 1	a i	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks)</p> <p>Correctly labelled diagram of reflux apparatus that works, with no safety problems</p> <p>AND</p> <p>An appreciation of most of the purification steps required to gain a pure sample</p>	6	<p>Indicative scientific points may include:</p> <p>Apparatus set up for reflux:</p> <ul style="list-style-type: none"> • round-bottom/pear shaped flask • heat source • condenser <p><i>Detail: water flow in condenser bottom to top; open system.</i></p> <p>Purification</p>



	<p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Labelled diagram of apparatus (either reflux or distillation) but with safety/procedural problems OR clear diagram of reflux apparatus without labelling AND Some details of further purification steps</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Diagram of apparatus (reflux OR separation OR distillation) drawn with no labelling OR labelled diagram with significant safety/procedural AND / OR Few or imprecise details about further purification stages</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks No response or no response worthy of credit.</p>	<p>Use of a separating funnel to separate organic and aqueous layers</p> <ul style="list-style-type: none">• <i>Detail: Collect lower organic layer density greater</i>• Drying with an anhydrous salt, <i>Detail: e.g. MgSO₄, CaCl₂, etc.</i>• Redistillation <i>Detail: Collect fraction distilling at 102°C.</i> <p><u>Examiner's Comments</u></p> <p>Candidates were not prepared to answer this type of question and the diagrams were hard to give credit to. Many had significant safety implications such as open beakers of butan-1-ol being heated by a Bunsen burner. Most mis-read the question and just outlined the method for purification and struggled to recall the practical details. Very few candidates mentioned the use of anhydrous salts, referring instead to 'boiling off' the water.</p> <p>Exemplar 4</p>
--	---	---



		<p style="text-align: center;"> $\text{Alcohol} \xrightarrow{\text{Reflux}} \text{Halalkane}$ </p> <p>5 (a) 1-Bromobutane is an organic liquid with a boiling point of 102°C.</p> <p>A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour.</p> <p>The equation is shown below.</p> $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{H}^+ + \text{Br}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{H}_2\text{O}$ <p>The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm⁻³) and an aqueous layer (density = 1.00 g cm⁻³).</p> <p>(ii) Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.</p>  <p>Heat under reflux. Do perform a distillation. Heat the reaction mixture in a round-bottom flask at just over 102°C. The butan-1-ol will react with sulfuric acid and sodium bromide to form 1-bromobutane, which evaporates and condenses and is collected in a flask. Water has a boiling point of 100°C so also evaporates and condenses and collects in the flask. Add the mixture in the collecting flask to a separating funnel. The organic layer should settle below the aqueous layer as it is denser. To confirm, add distilled water to the separating funnel, invert the funnel, and allow the layers to settle. The layer that gets bigger is the aqueous layer. Open the tap and run off the lower organic layer into a conical flask. Add drying agent to remove traces of water.</p> <p>This candidate was credited 4 marks for this level 2 answer. Although they have drawn distillation apparatus instead of reflux, they have considered the boiling point of the product, detailed using a separating funnel, a drying agent and that the lower organic layer would be drawn off first.</p>
ii	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = 12.6 (g) award 2 marks</p> <ul style="list-style-type: none"> $n(1\text{-bromobutane}) = 0.150 \times \frac{61.4}{100} = 0.0921 \text{ (mol)} \checkmark$ Mass 1-bromobutane = 0.0921 × 136.9 = 12.6 (g) ✓ <p style="text-align: right;">3 SF required</p>	<p style="text-align: center;">2</p> <p>Common errors: 33.4 (0.150 × 100/61.4 = 0.244 × 136.9) 1 mark</p> <p>ALLOW ECF for incorrect moles or incorrect M_r of 1-bromobutane (provided answer is to 3 SF) DO NOT ALLOW 6.82 (using M_r of butan-1-ol)</p> <p>ALLOW calculation using masses, e.g.</p> <p>Theoretical = 0.150 × 136.9 = 20.535 (g)</p> <ul style="list-style-type: none"> ✓ (ALLOW 20.535 rounded back to 20.5) Actual mass = 20.535 × $\frac{61.4}{100}$ = 12.6 (g) ✓ • (20.5 also gives 12.6) <p>Examiner's Comments</p>



					This question was well answered, but a significant number of candidates incorrectly used the Mr of butan-1-ol when calculating the mass of 1-bromobutane.
	b	<p>Tangent on graph drawn at approximately $t = 30$ min (± 10 mins) ✓</p> <p>Calculation of rate</p> <p>= Gradient (y/x) of tangent drawn e.g. $\frac{0.19}{72} = 2.64 \times 10^{-3} / 0.00264$ (mol dm⁻³min⁻¹) ✓</p>	2	<p>DO NOT ALLOW interpolation (taking a direct reading from graph), answer must be derived from taking a gradient</p> <p>ALLOW ecf from incorrectly drawn tangent</p> <p>Tolerance: Readings from y axis should be ± 0.01 mol dm⁻³ (i.e. within 1 square)</p> <p>Readings from x axis should be ± 5 minutes (i.e. within 0.5 of a square)</p> <p>IGNORE units IGNORE sign</p> <p><u>Examiner's Comments</u></p> <p>Most candidates knew they had to draw a tangent to the curve but calculating the gradient led to careless errors. Many drew tiny triangles and mis-read readings of coordinates. It is far easier, and more accurate, to use large triangles using the axes for coordinates. Lower ability candidates just interpolated the graph at 30s and were not credited marks for this.</p>	
		Total	10		
12 2		B	1 (AO 2.2)	<u>Examiner's Comments</u>	This proved problematical for many candidates with A being a common distractor.
		Total	1		
12 3		D	1 (AO 2.4)	<u>Examiner's Comments</u>	The majority of candidates were able to calculate the correct answer.
		Total	1		
12 4		FIRST, CHECK ANSWER ON ANSWER LINE IF answer = 95.9(%) award 4 marks	2		



$$[\text{H}^+] = 10^{-\text{pH}}$$

$$= 10^{-13.48} = 3.31 \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \checkmark$$

[OH⁻] from K_w

$$= \frac{1.00 \times 10^{-14}}{3.31 \times 10^{-14}} = 0.302 \text{ (mol dm}^{-3}\text{)} \checkmark$$

Mass of (NaOH)

$$= 0.302 \times \frac{100}{1000} \times 40.0 = 1.21 \text{ (g)} \checkmark$$

% of NaOH to 3 SF

$$= \frac{1.21}{1.26} \times 100 = 95.9 \text{ (%) } \checkmark$$

ALLOW ECF throughout

IGNORE rounding errors beyond 3rd SF throughout

ALLOW 3.3×10^{-14} (mol dm⁻³)

ALLOW 0.30

ALLOW 0.303 if 3.3×10^{-14} used in the first marking point

ALLOW pOH method:,

$$\text{pOH} = 14 - 13.48 = 0.52$$

$$[\text{OH}^-] = 10^{-0.52} = 0.302 \text{ (mol dm}^{-3}\text{)}$$

ALLOW $[\text{OH}^-] \times 0.1 \times 40$

Rounding $[\text{OH}^-]$ to 0.3(0) gives $1.2/1.26 = 95.2\%$

Award 4 marks

Rounding $[\text{OH}^-]$ to 0.303 gives $1.212/1.26 = 96.2\%$

Award 4 marks

Examiner's Comments

To help candidates, on this occasion early rounding was ignored and consequently most candidates scored full marks in this multi-step calculation. However, candidates should be advised not to round in the early stages of calculations such as this, as this introduces rounding errors into the final answer.

Candidates should be encouraged to indicate what they are attempting to calculate in unstructured calculations such as this.

The first step was frequently seen as $10^{-13.48} = 3.31... \times 10^{-14}$ which most examiners could take to be $[\text{H}^+]$. However, it is clearer to write $[\text{H}^+] = 10^{-13.48} = 3.31... \times 10^{-14} \text{ mol dm}^{-3}$. Even inclusion of units would help some candidates achieve partial credit as this might allow examiners to determine what a candidate is attempting to do.



		Total	4	
12 5	a	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF $M = 183$ AND Formula = Cl_2O_7 award 4 marks IF $M = 183$ award 3 marks</p> <p>-----</p> <p>Use of data and unit conversions</p> <div style="border: 1px solid black; padding: 5px;"> <ul style="list-style-type: none"> • $(R = 8.314)$ • T in K: 373K • V in m^3: 76.0×10^6 • (p in Pa: 1.00×10^5) ✓ </div> <p>Calculation of n $n = \frac{(1.00 \times 10^5) \times (76.0 \times 10^{-6})}{8.314 \times 373}$</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> $n = 2.45 \times 10^{-3} \text{ (mol) } \checkmark$ </div> <p>Molar mass</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> $M = \frac{m}{n} = \frac{0.4485}{2.45 \times 10^{-3}} = 183 \text{ (g mol}^{-1}\text{) } \checkmark$ </div> <p>Molecular formula</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> $\text{Cl}_2\text{O}_7 \checkmark$ </div>	<p>If there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>Correct value of n subsumes first mark</p> <p>ALLOW ECF from incorrectly calculated n</p> <p>ALLOW ECF from incorrect M if formula of Cl_xO_y is the closest to the with calculated value of M</p> <p>IGNORE use of $24\,000 \text{ cm}^3$ for calculation of n BUT then Mark molar mass and Molecular formula by ECF for two marks maximum.</p> $n = \frac{76.0}{24000} = 3.17 \times 10^{-3} \text{ (mol)}$ $M = \frac{0.4485}{3.17 \times 10^{-3}} = 141.6/141.5 \text{ (g mol}^{-1}\text{) } \checkmark$ <p>Molecular formula = $\text{Cl}_3\text{O}_2 \checkmark$</p> <p><u>Examiner's Comments</u></p> <p>Candidates found the unit conversion into the $pV = nRT$ equation difficult but were able to rearrange the equation to arrive at a value of n. They were then able to determine a molar mass by dividing n into 0.4485 g. Having arrived at 183.0 g mol^{-1}, it was expected that candidates would realise that there must be an even number of Cl atoms. The next step would be to subtract 71.0 from 183.0. This gives 112.0, which divides by 16.0 to give 7, thus leading to Cl_2O_7.</p> <p>The most common errors were seen in the unit conversions. Pressure is measured in Pa</p>	



				(not kPa), volume is measured in m ³ (not dm ³) and temperature is measured in K (in this case 373 K). Another source of error was to attempt to determine n by dividing the volume by 24,000 cm ³ .		
b	i	<p>Titres correct and ALL recorded to 2 decimal places</p> <table border="1" style="width: 100%;"> <tr> <td style="text-align: center;">Titre: 24.00 23.40 23.75 23.85 ✓</td> </tr> <tr> <td style="text-align: center;">mean titre = 23.80 (cm³) ✓</td> </tr> </table>	Titre: 24.00 23.40 23.75 23.85 ✓	mean titre = 23.80 (cm ³) ✓	2	<p>ALLOW 23.8 cm³</p> <p><u>Examiner's Comments</u></p> <p>It is clear candidates are not as experienced at filling in titration tables as might be expected. Every value in a titration table should be recorded to a second decimal place to an accuracy of ± 0.05 cm³.</p> <p>The average titre should be calculated by averaging concordant titres, i.e. those within 0.10 cm³ of each other.</p>
Titre: 24.00 23.40 23.75 23.85 ✓						
mean titre = 23.80 (cm ³) ✓						
	ii	<p>Percentage uncertainty $= \frac{0.05 \times 2}{23.40} \times 100 = 0.43$ (%) ✓</p>	1	<p>ALLOW ECF from incorrect subtraction in (i) or incorrect mean</p> <p>ALLOW 0.42% from titre values 2, 3 or 4 or mean titre or trial titre.</p> <p>2 DP required</p> <p><u>Examiner's Comments</u></p> <p>Candidates are unfamiliar with determination of percentage uncertainty. Marks were credited for any percentage uncertainty calculation correctly determined from any titre value, as many opted to choose the trial value as titre 1 or used an average titre.</p>		
	iii	<p>Add starch (near the end point) ✓</p> <p>Blue to colourless ✓</p>	2	<p>ALLOW blue/black OR black OR purple for colour of mixture</p> <p>ALLOW blue colour disappears (to colourless)</p>		



			<p>IGNORE 'clear' IGNORE 'colorimetry'</p> <p>Examiner's Comments</p> <p>Only the higher ability candidates realised starch needed to be added close to the end-point and this made the resulting colour change (blue-black to colourless) easier to see.</p> <p>The common error was to assume this was an acid-base titration and indicators such as methyl orange or phenolphthalein should be added.</p>
	iv	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF B = RbIO₃ AND relative formula mass = 260.5 award 5 marks IF relative formula mass = 260.5 award 4 marks</p> <p>-----</p> <p>$n(\text{S}_2\text{O}_3^{2-})$ in titration</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> $= \frac{0.150 \times 23.80}{1000} = 3.57 \times 10^{-3} \text{ (mol) } \checkmark$ </div> <p>$n(\text{IO}_3^-)$ in titration</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> $= 10 \times 5.95 \times 10^{-4} = 5.95 \times 10^{-3} \text{ (mol) } \checkmark$ </div> <p>$n(\text{IO}_3^-)$ in original 250 cm³</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> $= \frac{3.57 \times 10^{-3}}{6} = 5.95 \times 10^{-4} \text{ (mol) } \checkmark$ </div> <p>Relative formula mass of B $= \frac{1.55}{5.95 \times 10^{-3}} = 260.5 \text{ (g mol}^{-1}\text{) } \checkmark$</p> <p>Formula of B (must be derived from relative formula mass)</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> <p>Iodate of Group 1 metal that most closely matches calculated molar mass of B</p> <p>Formula from 260.5 = RbIO₃ ✓</p> </div>	<p>5</p> <p>ALLOW ECF from incorrect mean titre in (a)(i)</p> <p>ECF from $n(\text{S}_2\text{O}_3^{2-})$ in titration ALLOW a two-step calculation $n(\text{I}_2) = n(\text{S}_2\text{O}_3^{2-}) \div 2$ and $n(\text{IO}_3^-) = n(\text{I}_2) \div 3$</p> <p>ECF from $n(\text{IO}_3^-)$ in titration</p> <p>ECF from $n(\text{IO}_3^-)$ in original 250 cm³</p> <p>IF scaling $\times 10$ is omitted, ALLOW ECF from $n(\text{IO}_3^-)$ in titration</p> <p>ALLOW ECF from incorrect RFM of B provided metal is from Group 1 ALLOW RbIO₃- DO NOT ALLOW RbIO₃ without relative formula mass value. DO NOT ALLOW 260.4 (without working) and RbIO₃ IF B = RbIO₃ AND relative formula mass =</p>



			261 award 5 marks
			<p>Examiner's Comments</p> <p>This unstructured calculation was done well by the higher ability candidates. Lower ability candidates struggled to show what they were attempting to calculate and in particular did not appreciate the 1 : 6 ratio of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ to $\text{IO}_3^-(\text{aq})$.</p> <p>Candidates might be advised to start $n(\text{formula}) = \dots$ at the start of each line of calculation</p> <p>eg $n(\text{S}_2\text{O}_3^{2-}) = \dots$ mol</p> <p>No credit was given to candidates who grasped the identity of the Group 1 iodate from nowhere and calculated the theoretical relative formula mass.</p>
		Total	14
12 6	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) All three reactions are covered in detail with C, D, E and F identified with clear explanations.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured with clear chemical communication and few omissions. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) All three reactions are covered but explanations may be incomplete OR Two reactions are explained in detail.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is relevant e.g. formulae may contain missing brackets or numbers and supported by some evidence.</i></p> <p>Level 1 (1–2 marks)</p>	<p>Indicative scientific points may include:</p> <p>REACTION 1 ($\text{CuSO}_4/\text{NH}_3$) Product</p> <p>C : $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$</p> <p>Equation</p> $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ <p>6 Structure of trans stereoisomer</p> <p>Correct connectivity</p> <p>REACTION 2 ($\text{Cu}_2\text{O}/\text{H}_2\text{SO}_4$) Products</p> <p>D : CuSO_4 OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ E: Cu</p>	



Make two simple explanations from any one reaction.

OR

Makes one simple explanation from each of two reactions

There is an attempt at a logical structure with a line of reasoning The information is in the most part relevant.

0 marks No response worthy of credit.

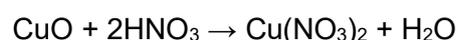
Equation



Oxidation numbers



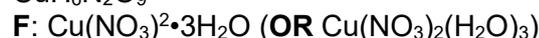
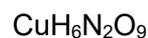
REACTION 3 (CuO/HNO₃) Equation



Molar ratios

$$\begin{array}{cccc} \text{Cu} & : & \text{H} & : & \text{N} & : & \text{O} \\ = & \frac{26.29}{63.5} & : & \frac{2.49}{1.0} & : & \frac{11.59}{14.0} & : & \frac{59.63}{16.0} \end{array}$$

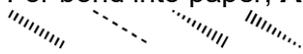
Formula of F

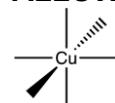


Further guidance on use of wedges

Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper
 • **OR** 4 lines, 1 'out wedge' and 1 'in wedge':

For bond into paper, **ALLOW**:

•  **ALLOW** following geometry:



Examiner's Comments

Many candidates had a stab at identifying **C-F** but neglected to include equations for the three reactions described or to show relevant working.

Most candidates recognised **C** as the ammoniacal copper(II) ion but the formula was frequently incorrect and correct attempts

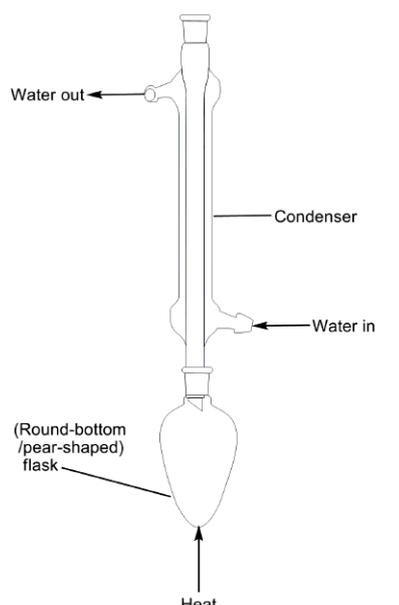


			<p>at a ligand substitution equation from $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ was rarely seen. Diagrams showing the <i>trans</i> isomer were attempted but often of poor quality due to incorrect linking.</p> <p>Candidates recognised D as being CuSO_4 but often did not identify E as Cu due to a lack of familiarity with this common disproportionation reaction. $\text{Cu}(\text{OH})_2(\text{s})$ was a common incorrect identification of E. Only the best responses described the oxidation number changes which made this a disproportionation reaction.</p> <p>F was identified by a percentage by mass calculation to determine an empirical formula and then by deduction to produce $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$. Having done this, many candidates did not give the relatively simple equation for reaction 3 between copper(II) oxide and dilute nitric acid.</p> <p>Exemplar 2</p>
--	--	--	---



				<p>(d)* Three different reactions of copper compounds are described below.</p> <p>Reaction 1: Aqueous copper(II) sulfate reacts with excess aqueous ammonia in a ligand substitution reaction. A deep-blue solution is formed, containing an octahedral complex ion, C, which is a <u>trans isomer</u>. \Rightarrow 1p0</p> <p>Reaction 2: Copper(I) oxide reacts with hot dilute sulfuric acid in a disproportionation reaction. A blue solution, D, and a brown solid, E are formed. $\text{Cu}_2\text{O} + \text{H}_2\text{SO}_4$</p> <p>Reaction 3: Copper(I) oxide reacts with warm dilute nitric acid in a neutralisation reaction, to form a blue solution. Unreacted copper(I) oxide is filtered off, and the solution is left overnight in an evaporating basin. A hydrated salt, F, crystallises, with the percentage composition by mass: Cu, 26.29%; H, 2.48%; N, 11.59%; O, 59.63%.</p> <p>Identify C-F by formulae or structures, as appropriate.</p> <p>Include equations, any changes in oxidation number, and working. [6]</p> <p>① $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$</p> <div style="border: 1px solid black; padding: 5px; display: inline-block;"> $\begin{array}{c} \text{H}_2\text{N} \quad \text{OH}_2 \\ \quad \\ \text{H}_2\text{N} \quad \text{Cu} \\ \quad \\ \text{H}_2\text{N} \quad \text{OH}_2 \end{array}$ <p>octahedral</p> </div> <p>This is the <u>trans isomer C</u> because the H_2O ligands are 180° apart.</p> <p>② $\text{Cu}_2\text{O} + \text{H}_2\text{SO}_4 \rightarrow \text{Cu}_2\text{O} + \text{CuSO}_4 + \text{H}_2\text{O}$ brown solid blue solution E D</p> <p>③ $\text{Cu}_2\text{O} + 2\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O}$</p> <table border="1" style="width: 100%; text-align: center;"> <tr> <td></td> <td>Cu</td> <td>H</td> <td>N</td> <td>O</td> </tr> <tr> <td>mass</td> <td>26.29</td> <td>2.48</td> <td>11.59</td> <td>59.63</td> </tr> <tr> <td>rfm</td> <td>63.5</td> <td>1</td> <td>14</td> <td>16</td> </tr> <tr> <td>mol</td> <td>0.414</td> <td>2.48</td> <td>0.828</td> <td>3.73</td> </tr> </table> <p>Additional answer space if required.</p> <p style="text-align: center;">1 : 6 : 2 : 9 $\Rightarrow \text{CuH}_6\text{N}_2\text{O}_9$</p> <p>A hydrated salt is made up of an anhydrous salt with water of crystallisation. $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ (F) and molecular. \Rightarrow This fits the empirical formula.</p> <p><u>NOTE:</u> ② The oxidation number of Cu goes from +1 to 0 in Cu_2O, and from +1 to +2 in CuSO_4. Cu⁺ is reduced to form Cu and oxidised to form Cu²⁺ in CuSO_4. [3]</p>		Cu	H	N	O	mass	26.29	2.48	11.59	59.63	rfm	63.5	1	14	16	mol	0.414	2.48	0.828	3.73
	Cu	H	N	O																				
mass	26.29	2.48	11.59	59.63																				
rfm	63.5	1	14	16																				
mol	0.414	2.48	0.828	3.73																				
		Total	6																					
12 7		C	1	<p>Examiner's Comments</p> <p>A lot of work was required to determine the equation with the lowest atom economy. Some candidates selected C after calculating a value for each equation, while stronger candidates appeared to focus on HBr as a by-product with a relatively high molar mass. Many incorrect responses were seen and candidates appeared to pick A, B and D in roughly equal proportions.</p>																				
		Total	1																					

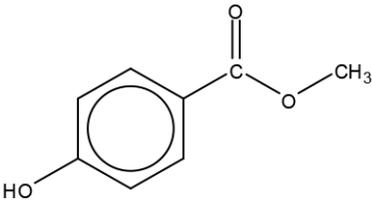
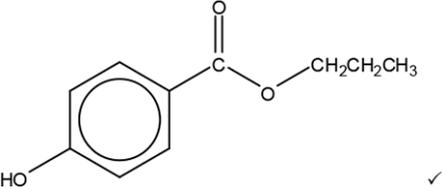
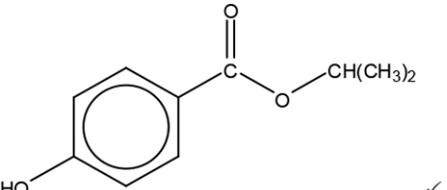


12 8	i	<p>Diagram Diagram showing round bottom/pear shaped flask AND upright condenser ✓</p>  <p>Labels (Round-bottom/pear-shaped) flask AND condenser AND water in at bottom and out at top AND heat (source) ✓</p>	2	<p>DO NOT ALLOW conical flask, volumetric flask, beaker in place of round bottom/pear shaped flask</p> <p>DO NOT ALLOW distillation</p> <p>DO NOT ALLOW stopper/bung on top of condenser</p> <p>IGNORE a thermometer in condenser</p> <p>IGNORE a small gap between flask and condenser</p> <p>ALLOW diagram of heating apparatus as an alternative to heat label</p> <p>Examiner's Comments</p> <p>Most candidates were able to draw a suitable diagram to show the apparatus required for reflux but some included a stopper on top of the condenser. Many of the diagrams were labelled appropriately but common errors included incorrect direction of water flow or omission of the 'flask' label. A small but significant proportion of candidates drew a diagram showing distillation.</p>
	ii	<p>Precipitate G 1 mark</p> <p>silver bromide/AgBr AND $M = 1.88/0.01 = 188 \text{ (g mol}^{-1}\text{)}$ $188 - 107.9 = 80.1 \text{ (so halide is Br}^{-}\text{)} \checkmark$</p> <p>Alcohol F and Haloalkane E 2 marks</p>	3	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>Note: working is required for first mark</p> <p>ALLOW use of 108 as Ar of Ag</p>



		<p>E and F clearly identified</p> <p>F/alcohol: butan-2-ol</p> $ \begin{array}{c} \text{H} \quad \text{OH} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array} $ <p>E/haloalkane: E is haloalkane of C₄H₉X with</p> <ul style="list-style-type: none"> • same halogen as G AND • same carbon chain as F ✓ 		<p>Note: E and F can be identified by correct name or structure BUT IGNORE incorrect names</p> <p>Examiner's Comments</p> <p>This question, requiring candidates to analyse the information to identify compounds E, F and G, discriminated well. Many candidates deduced that G was a silver halide but not all provided working to back up their choice of AgBr. Some candidates appeared to guess and AgCl was commonly seen. Some candidates used the molar mass of F provided to deduce the molecular formula of C₄H₁₀O but lower ability responses did not process this further. Higher ability candidates identified F as butan-2-ol, showing the chiral carbon clearly. Other alcohols were also seen including butan-1-ol and methylpropan-2-ol. The highest ability candidates linked all the information and provided a structure for E that was consistent with their suggestions for F and G.</p>
		Total	5	
12 9	i	<p>FIRST CHECK ANSWER ON ANSWER LINE IF answer = 7.5×10^{-4} award 2 marks</p> <p>-----</p> <p>[K] in mol dm⁻³</p> $\frac{9.13 \times 10^{-2}}{166} = 5.50 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>[L] from peak areas</p> $5.50 \times 10^{-4} \times \frac{5.9}{4.3} \quad \text{OR } 5.50 \times 10^{-4} \times 1.37 \dots$ $= 7.5 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>2 SF Required</p>	2	<p>If there is an alternative answer, Apply ECF</p> <p>Alternative method</p> <p>[K] in g dm⁻³ with peak area of 5.9</p> $9.13 \times 10^{-2} \times \frac{5.9}{4.3} \quad \text{OR } 9.13 \times 10^{-2} \times 1.37$ $= 0.125 \text{ OR } 0.13 \text{ (g dm}^{-3}\text{)} \checkmark$ <p>Calculator: 0.125272093</p> <p>[L] in mol dm⁻³</p> $\frac{0.125}{166} = 7.5 \times 10^{-4}$ <p>OR $\frac{0.13}{166} = 7.8 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>-----</p> <p>Common errors: Common errors: Award 1 mark for:</p>



				<ul style="list-style-type: none"> • 0.099 (from $\frac{9.13 \times 10^{-2}}{166} \times 180$) • 6.9×10^{-4} (from $\frac{0.125}{180}$) • 7.2×10^{-4} (from $\frac{0.13}{180}$) • 7.0×10^{-4} (from $\frac{0.25272093}{180}$) <p>Examiner's Comments</p> <p>This question required candidates to apply their knowledge of gas chromatography and the mole to solve this problem. Most candidates recognised the need to use the relative peak areas to determine the relative proportion of M. Many also realised that division by the molar mass was required to ensure the final answer was given in mol dm⁻³. However, some used molar mass of M rather than K in this step, leading to an answer of 7.0×10^{-4} mol dm⁻³.</p> <p>Answer = 7.5×10^{-4} mol dm⁻³</p>
	<p>ester J</p>  <p style="text-align: right;">✓</p>			
ii	<p>esters L and M</p>  <p style="text-align: right;">✓</p>  <p style="text-align: right;">✓</p>		3	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>L and M can be identified either way round</p> <p>IGNORE 'C₃H₇' in L and/or M as ambiguous (<i>question requires structures</i>)</p> <p>IGNORE connectivity of phenol OH group (<i>marks are for structures of alkyl groups</i>)</p> <p>Examiner's Comments</p> <p>Examiners were encouraged by the number of good responses to this problem solving question. Most candidates achieved at least one mark in this part, often from a correct structure of J. Although many candidates deduced that the R group for both L and M</p>



				consisted of 3 C atoms and 7 H atoms, only the highest ability candidates were able to join these correctly. A small but significant number of responses showed R groups that involved O atoms, despite the prompt that the R represented an alkyl group. Candidates are advised to read questions carefully.
			Total	5
13 0	a	i	<p> $n(\text{CO}_2) = 2.97/44 = 0.0675 \text{ (mol)} \checkmark$ $n(\text{H}_2\text{O}) = 1.62/18 = 0.0900 \text{ (mol)} \checkmark$ Ratio of C : H 3 : 8 \checkmark Molecular formula $\text{C}_3\text{H}_8\text{O}_2 \checkmark$ Structure any correct structure of $\text{C}_3\text{H}_8\text{O}_2 \checkmark$ e.g. <pre> H H H HO-C-C-C-OH H H H </pre> OR <pre> H H H H-C-O-C-O-C-H H H H </pre> etc </p>	<p>Consult your team leader if an alternative creditworthy approach is seen</p> <p>IGNORE ratio of CO_2 to H_2O is 3:4 ALLOW this mark from the correct molecular formula OR a correct structure if not shown in working</p> <p>DO NOT ALLOW an incorrect molecular formula</p> <p>Mark independently from molecular formula but structure MUST contain 3C, 8H and 2O</p> <p>5 ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW any vertical bond to the OH group e.g. ALLOW</p> <pre> OH OR HO </pre> <p>DO NOT ALLOW OH-</p> <p>Examiner's Comments</p> <p>The majority of candidates approached this problem by initially calculating the number of moles of CO_2 and H_2O produced. Many candidates were able to process these amounts to deduce the molecular formula for N, as shown in Exemplar 11. Alternate approaches were seen, but with much less</p>



frequency.

Exemplar 11

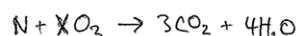
$$2.57g \div (12+32) = 0.0675 \text{ mol CO}_2 \quad \checkmark$$

$$1.62g \div (2+16) = 0.09 \text{ mol H}_2\text{O} \quad \checkmark$$

$$1.7g \div (76) = 0.0225 \text{ mol N} \quad \checkmark$$

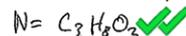
$$0.0675 \div 0.0225 = 3$$

$$0.09 \div 0.0225 = 4$$

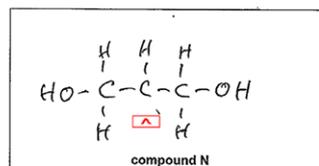


$$3(12) + 8 = 44$$

$$76 - 44 = 32$$



$$\frac{32}{16} = 2 \text{ O}$$



[5]

This response is logically presented with clear working demonstrating the candidate's approach. In the first part the candidate determines the amount, in moles, of carbon dioxide and water produced. This response uses the number of moles of **N** to deduce the molar ratio of CO₂ to H₂O. Other candidates obtained this by dividing the moles of carbon dioxide by the moles of water.

The candidate uses a balanced equation to deduce the molar ratio of C to H in **N**; this is an excellent strategy that is worth highlighting



				<p>to future candidates. The working on the right hand side shows how the amount of O in compound N is determined.</p> <p>It is a shame that the structure suggested has one H atom missing, as this omission has prevented full marks from being credited. Candidates are encouraged to check structures carefully to ensure that all atoms are drawn with the correct number of bonds.</p>
	ii	<p>Carbonyl compound identified as propanone ✓</p> <p>Rest of equation ✓</p>	2	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>Examiner's Comments</p> <p>Many candidates found this demanding question very difficult. Some were able to deduce that propanone was the carbonyl compound in the reaction. Only the most able recognised that water was a by-product of this reaction.</p>
	b	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) Compound is a structure of C₆H₁₂O₃ that is consistent with splitting pattern and chemical shifts in NMR spectrum. AND Comprehensive reasoning with most of the data analysed.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Compound has a feasible chemical structure that is consistent with the splitting pattern in NMR spectrum but may have incorrect molecular formula. AND Reasoning provided with some of the data analysed.</p> <p><i>There is a line of reasoning presented with some structure. The information presented</i></p>	6	<p>Indicative scientific points:</p> <p>Empirical and Molecular Formula</p> <ul style="list-style-type: none"> • C : H : O = 54.54/12 : 9.10/1 : 36.36/16 4.545 : 9.10 : 2.273 2 : 4 : 1 • Empirical formula = C₂H₄O • uses <i>m/z</i> = 132.0 to determine molecular formula as C₆H₁₂O₃ <p><u>¹H NMR analysis</u></p> <p>Spectrum:</p> <ul style="list-style-type: none"> • δ = 4.0 ppm, quartet, 1H, CH₃–CH–O • δ = 1.3 ppm, singlet, 6H, (CH₃)₂–C • δ = 1.2 ppm, doublet, 3H, CH₃–CH– <p>Without D₂O:</p> <ul style="list-style-type: none"> • Peak at 11.0 ppm COOH or OH • peak at 3.6 ppm OH



is relevant and supported by some evidence.

Level 1 (1–2 marks)

Correct determination of empirical formula and/or molecular formula.

OR

Analyses most of the NMR data.

OR

Attempts to determine empirical and/or molecular formula

AND analyses some of the NMR data.

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks

No response or no response worthy of credit.

Note: Data Sheet shows O-H chemical shift can occur around 11.0 ppm

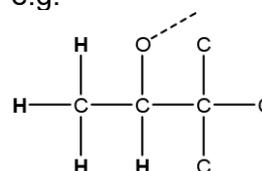
Structure

ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

Contains

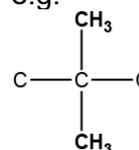
- region that gives doublet and quartet

e.g.

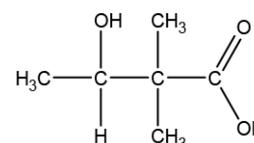


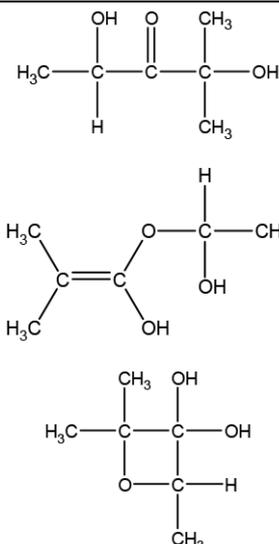
- region that gives singlet

e.g.



Examples of structures consistent with splitting and chemical shift in NMR





Note: there may be other possible structures that are consistent with the splitting pattern and chemical shifts in NMR – if an alternative structure is seen, please contact your team leader

Examiner's Comments

Most candidates were able to determine the empirical and molecular formula of the unknown compound. A number of excellent and clear responses were seen, where the NMR data was explained, including interpretation of the additional peaks observed without D₂O. However many candidates were unable to suggest a structure that matched their NMR interpretation. Some candidates used the quartet, doublet and singlet to suggest a structure that would give rise to this splitting pattern, but which was not consistent with the chemical shifts, see Exemplar 12. Such responses received a level 2 mark (3-4). Stronger responses were able to use all the data to suggest a correct structure. The most common was CH₃CH(OH)C(CH₃)₂COOH although other viable structures, including CH₃CH(OH)COC(CH₃)₂OH, were also seen. Examiners were impressed with the problem solving ability shown by candidates and a significant proportion of responses were credited six marks.

Exemplar 12



			<p> $\begin{array}{ccc} \text{C} & \text{H} & \text{O} \\ 54.54 & 9.10 & 36.36 \\ 12 & 1 & 16 \\ 4.545 & 9.10 & 2.2725 \\ 2 & 4 & 1 \end{array}$ $\frac{12}{44} = 3 \quad \frac{1}{44} = 1 \quad \frac{16}{44} = 3$ empirical formula = $\text{C}_3\text{H}_4\text{O}_3$ $M_r = 44$ $\frac{132}{44} = 3$ molecular formula = $\text{C}_3\text{H}_4\text{O}_3 \times 3 = \text{C}_6\text{H}_{12}\text{O}_6$ peak at 1.2 ppm = CH₃-R $\text{H}_3\text{C}-\text{R}$ H_3C doublet so adjacent carbon has 1 H. peak integral of 3 $\rightarrow \text{CH}_3$ peak at 1.3 ppm = $\text{HC}-\text{R}$ singlet so adjacent C has no protons. integral of 6 = $(\text{CH}_2)_2$ Peak at 4.0 ppm indicative of $\text{HC}-\text{O}$. Quartet so adjacent C has 3 protons. Integral of 1 = CH Additional answer space if required. D_2O at 11 ppm = $-\overset{\text{O}}{\text{C}}-\text{OH}$ and 3.6 ppm indicative of $\text{HC}-\text{O}$. M.f. = $\text{C}_6\text{H}_{12}\text{O}_6$ </p>
			<p> This logically presented Level 2 response uses the elemental analysis and mass spectrum data to determine the correct empirical and molecular formula of the unknown compound. The peaks in the NMR spectrum are analysed in detail, with a clear explanation of the splitting patterns. A comment about the two additional peaks observed when the spectrum is run without D_2O is also provided. The response concludes with a structure of $\text{C}_6\text{H}_{12}\text{O}_3$ that would show a singlet, doublet and quartet in its ^1H NMR spectrum. However, this structure is not consistent with the chemical shift values shown in the spectrum provided. In particular this structure would produce a quartet between 2.0–2.9 ppm, rather than at 4.0 as in the spectrum shown. Consequentially this response does not achieve Level 3. When tackling questions of this type candidates are advised to check that a proposed structure would produce peaks in the correct region of the NMR spectrum to ensure it is totally consistent with the data analysed. </p>
		Total	13

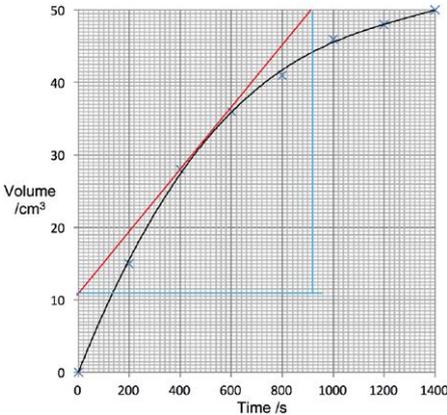


13 1	i	Hydrogen/H ✓	1	<p>ALLOW H₂</p> <p><u>Examiner's Comments</u></p> <p>Most candidates were credited this straightforward mark and identified that hydrogen would gain an electron to form a 1- ion. Some candidates opted for lithium, able to form an ion with the same electron configuration as helium, but with a 1+ rather than a 1- charge.</p> <p>Candidates are recommended to look closely at the requirements of the question set.</p>
	ii	Helium/He ✓	1	<p><u>Examiner's Comments</u></p> <p>This part required candidates to recall their knowledge of trends in first ionisation energy. Candidates found this part harder than 1(a)(i) with only the higher ability candidates choosing the correct response of 'helium'.</p> <p>Many candidates instead chose another noble gas, with neon and argon commonly seen. Other common incorrect responses were hydrogen and fluorine.</p>
	iii	Magnesium/Mg ✓	1	<p><u>Examiner's Comments</u></p> <p>Most candidates did correctly select magnesium, but many other elements were seen, especially aluminium, silicon, beryllium and calcium.</p> <p>To identify the element's group, candidates needed to analyse the data to find the large increase in ionisation energy corresponding to a change in shell. From the responses, some candidates did not make use of 'Period 3' in the stem.</p>
	iv	Sulfur/S ✓	1	<p>ALLOW sulphur; S₈</p> <p><u>Examiner's Comments</u></p> <p>Most candidates selected sulfur as the correct response, recalling their knowledge of molecular shapes encountered early in the course. There was no real pattern for incorrect responses, suggesting that they were guesses.</p>



	v	Chlorine/Cl OR fluorine/F ✓	1	<p>ALLOW Cl₂ OR F₂</p> <p><u>Examiner's Comments</u></p> <p>Most candidates chose the correct response of chlorine, although hydrogen was a common incorrect response, presumably by linking to the acidic properties of H⁺ ions. Other candidates focused on 'reacts with water' and chose sodium (which does form a solution with water, but on that is alkaline rather than acidic).</p>
	vi	Phosphorus/P ✓	1	<p>ALLOW P₄</p> <p><u>Examiner's Comments</u></p> <p>Almost all candidates correctly responded with phosphorus and this was the easiest part of 1(a).</p>
	vii	Carbon/C ✓	1	<p>ALLOW silicon/Si</p> <p><u>Examiner's Comments</u></p> <p>Most candidates correctly selected carbon. From their A Level studies, candidates would expect hydrogen to have an oxidation number of +1 and to form compounds with carbon (CH₄) and silicon (SiH₄) in which the element has an oxidation number of -4. Although hydrogen is actually slightly less electronegative than carbon, hydrogen is slightly more electronegative than silicon. Therefore, in the case of SiH₄, silicon has an oxidation number of +4. A response of silicon still indicates a correct understanding of oxidation number rules and was also credited</p>
	viii	Oxygen/O ✓	1	<p>ALLOW O₂</p> <p><u>Examiner's Comments</u></p> <p>This proved to be the hardest part of 1(a) with only the higher ability candidates selecting oxygen. Sulfur proved to be the key distractor, having the same molar mass as O₂. Most candidates did not consider that the element was gaseous and could not be sulfur.</p>
		Total	8	



13 2	i	<p>Graph</p> <p>Graph of volume (y axis) against time (x axis) AND Axes labelled with correct units AND At least half graph paper in both directions AND Linear scales ✓</p> <p>Points</p> <p>7 points from 200–1400 s plotted ✓ <i>Point at 0,0 not required</i></p> <p>Line</p> <p>Curve drawn through origin (0,0) ✓ AND Curve not drawn with straight lines between points.</p> <p>Rate</p> <p>Attempted tangent on graph drawn to curve at $t = 500 \pm 100$ s ✓</p> <p>Rate calculated in range 0.037–0.047 ($\text{cm}^3 \text{s}^{-1}$) ✓</p> <p><i>e.g. for graph in guidance: $\frac{50 - 11}{920 - 0} = 0.042$</i></p> <hr/> <p>For tangents not drawn at 500 ± 100 s,</p> <ul style="list-style-type: none"> • ALLOW ECF ONLY for a tangent drawn to the candidate's line. • Then calculate the gradient from candidate's tangent. <p>For inverse graphs of time against volume,</p> <ul style="list-style-type: none"> • Graph mark will not be scored. • All other marks are available. • BUT rate = $1/\text{gradient} = 0.037\text{--}0.047$ ($\text{cm}^3 \text{s}^{-1}$) 	5	 <p>ALLOW V OR Vol for volume ALLOW t for time For 's', ALLOW sec, seconds, etc</p> <p>CARE: Use of x and y coordinates at $t = 500$ s scores zero,</p> <p>e.g. For volume = 33 cm^3 and time = 500 s, x and y coordinates gives $33/500 = 0.066 \times \times$</p> <p>Examiner's Comments</p> <p>The graph was generally well drawn although many didn't realise that a tangent needed to be drawn. A few tried to draw a straight line of best fit, rather than a curve.</p> <p>Most candidates were able to construct a correct graph, assigning the axes correctly and making good use of the graph paper. Points were usually plotted correctly and most candidates made a good attempt to draw a curved line of best fit. Candidates then needed to draw a tangent at 500 seconds and to measure its gradient to calculate the rate. Lower ability candidates did not draw a tangent to their curve and just calculated the volume formed at 500 seconds.</p>
	ii	<p>FIRST CHECK THE ANSWER ON ANSWER LINE</p>	3	<p>ALLOW ECF throughout</p>



If answer = 0.092 (mol dm⁻³) award 3 marks

$$n(\text{O}_2) = \frac{55}{24000} = 2.29 \times 10^{-3} \text{ (mol) } \checkmark$$

$$n(\text{H}_2\text{O}_2) = 2.29 \times 10^{-3} \times 2 = 4.58 \times 10^{-3} \text{ (mol) } \checkmark$$

$$[\text{H}_2\text{O}_2] = \frac{4.58 \times 10^{-3} \times 1000}{50.0} = 0.092 \text{ (mol dm}^{-3}\text{)} \checkmark$$

(2 SF)

ALLOW 2 SF up to calculator value of $2.291666667 \times 10^{-3}$

ALLOW calculation using ideal gas equation provided that $p = \sim 10^5$ Pa and T in range 293–298 K.

ALLOW use of 8.31 for R (gives same answer)

$$\text{e.g. } n(\text{O}_2) = \frac{1 \times 10^5 \times 55 \times 10^{-6}}{8.314 \times 298} = 2.22 \times 10^{-3} \text{ (mol) } \checkmark$$

$$n(\text{H}_2\text{O}_2) = 2.22 \times 10^{-3} \times 2 = 4.44 \times 10^{-3} \text{ (mol) } \checkmark$$

$$[\text{H}_2\text{O}_2] = \frac{4.44 \times 10^{-3} \times 1000}{50.0} = 0.089 \text{ (mol dm}^{-3}\text{)} \checkmark$$

(2 SF)

NOTE: 293 K gives 0.090 (mol dm⁻³)

Common errors

0.046 → 2 marks no × 2 for $n(\text{H}_2\text{O}_2)$

Examiner's Comments

Most candidates calculated the initial concentration of 0.092 mol dm⁻³, although many ignored the two significant figures requirement with 0.0916 and 0.09 being seen commonly.

Almost all candidates corrected calculated that 55 cm³ O₂ contains 2.29×10^{-3} mol O₂(g) and multiplied this value by 2 to obtain 4.58×10^{-3} mol H₂O₂ in 50 cm³ of solution.

Fewer candidates scaled up this value to 1 dm³ with many dividing by 20 (instead of × 20) or using 55 cm³, the initial volume of O₂(g) rather than the volume of the H₂O₂ solution.

Exemplar 3 shows a clear response where each step in the calculation can be clearly seen.

Exemplar 4 is more difficult to follow as the candidate has not indicated what the moles apply to. It is possible though to see that the scaling up by 2 for H₂O₂ has been omitted



				<p>and the final answer (0.046) is half of the correct answer (0.092). It is then possible to award the final mark by error carried forward.</p> <p>Exemplar 3</p> <p>(ii) The student allows the reaction in equation 2.1 to proceed until no more gas is evolved. The volume of O_2 in the syringe is now 55 cm^3, measured at RTP.</p> <p>Calculate the initial concentration of the H_2O_2.</p> <p>Give your answer to <u>two</u> significant figures.</p> $n(O_2) = \frac{55}{24000} = 2.291... \times 10^{-3} \text{ mol}$ $\therefore n(H_2O_2) = 2 \times 2.291... \times 10^{-3} = 4.582... \times 10^{-3} \text{ mol}$ $[H_2O_2] = \frac{4.582... \times 10^{-3}}{\frac{50}{1000}} = 0.0916... \text{ mol dm}^{-3}$ <p>initial concentration of $H_2O_2 = 0.092 \text{ mol dm}^{-3}$ [3]</p> <p>Exemplar 4</p> <p>Give your answer to two significant figures.</p> $n = \frac{V}{V_m} = \frac{55}{24000} = 0.00229167$ $m = n \times c = 0.00229167 \times 50 = 0.1145835$ $c = \frac{m}{V} = \frac{0.1145835}{2.5} = 0.0458334$ <p>initial concentration of $H_2O_2 = 0.046 \text{ mol dm}^{-3}$ [3]</p>
		Total	8	
13 3	i	Colourless to yellow ✓	1	<p>IGNORE clear for colourless</p> <p>Examiner's Comments</p> <p>Candidates were expected to apply their knowledge of the colour change in a manganate(VII) titration to this novel situation. Most candidates incorrectly showed the inverse colour change of yellow → colourless.</p>
	ii	<p>Mean titre</p> $= \frac{(23.15 + 23.25)}{2} = 23.2(0) \text{ (cm}^3\text{)} \checkmark$ <p>Analysis of results 5 marks</p> $n(\text{Ce}^{4+}) = 23.20 \times \frac{0.0500}{1000} = 1.16 \times 10^{-3} \text{ (mol)} \checkmark$ $n(\text{(COOH)}_2) \text{ in } 25.0 \text{ cm}^3 = \frac{1.16 \times 10^{-3}}{2} = 5.8(0) \times 10^{-4} \text{ (mol)} \checkmark$ $n(\text{(COOH)}_2) \text{ in } 250 \text{ cm}^3$	6	<p>Common error: Incorrect mean from all 3 titres = 23.30 cm^3</p> <p>Use ECF throughout Intermediate values for working to at least 3 SF. TAKE CARE as value written down may be truncated value stored in calculator. Depending on rounding, either can be credited.</p> <hr/> <p>COMMON ERRORS: Mean of 23.30 (use of all 3 titres) → 0.634%: 5 marks</p> <p>TAKE CARE for final answer of 0.63 seen.</p>



	<p>$= 5.8(0) \times 10^{-4} \times 10 = 5.8(0) \times 10^{-3} \text{ (mol)}$ ✓</p> <p>Mass $(\text{COOH})_2 = 5.8(0) \times 10^{-3} \times 90.0 = 0.522 \text{ g}$ ✓</p> <p>% oxalic acid = $\frac{0.522 \times 100}{82.68} = 0.631\%$ ✓</p> <p>Percentage MUST be expressed to 3 SF</p>	<ul style="list-style-type: none">• No final mark as only 2 SF 0.63 may have been rounded from 0.631 (from correct mean)• OR from 0.634 (using mean from all 3 titres) <p>Check back to mean titre.</p> <p>No $\div 2$ to <i>obtain</i> $n((\text{COOH})_2)$</p> <p>→ 1.26%: 5 marks from 23.20 → 1.27% 4 marks from 23.30</p> <p><u>Examiner's Comments</u></p> <p>Most candidates answered this unstructured titration calculation well, with almost all responses gaining some credit. Most coped well with the 1:2 reaction stoichiometry and the need to scale up to 250 cm³.</p> <p>Common errors included the following.</p> <ul style="list-style-type: none">• Taking the mean of all three titres (23.30 cm³) instead of the closest titres (23.20 cm³).• Not considering the 1:2 stoichiometry.• Not scaling up to 250 cm³.• Giving the final answer to two rather than three significant figures; this was the most common error. <p>The question required the final answer to be given to an appropriate number of significant figures. Many candidates seemed to be unaware that this reflects the least significant figures provided in the data, in this case three significant figures. Candidates are also advised to only round at the end of a multi-step calculation. Rounding of intermediate values introduces rounding errors in the final answer.</p> <p>The example shows a perfect response with each step clearly described, leading to the correct concentration of ethanedioic acid. Candidates should present their calculations clearly. If there is a mistake at any stage, this can be easily identified, allowing for error</p>
--	---	--



				<p>carried forward to be applied for any subsequent good method.</p> <p>Exemplar 6</p> <p>mean titre value = $\frac{23.25 + 23.15}{2} = 23.20$ ✓</p> <p>volume of $\text{Ce}(\text{SO}_4)_2 = 0.0232 \text{ dm}^3$ ✓</p> <p>Conc of $\text{Ce}(\text{SO}_4)_2 = 0.05 \text{ mol dm}^{-3}$</p> <p>moles of $\text{Ce}(\text{SO}_4)_2 = 1.16 \times 10^{-3} \text{ mol}$</p> <p>25 cm³ of ethanedioic acid reacts with $1.16 \times 10^{-3} \text{ mol of Ce(SO}_4)_2$</p> <p>moles of ethanedioic acid in 25 cm³ = 5.8×10^{-4}</p> <p>moles of ethanedioic acid in 250 cm³ = 5.8×10^{-3}</p> <p>mass of ethanedioic acid extracted:</p> <p>mass = moles \times Mr</p> <p>= $5.8 \times 10^{-3} \times 90 = 0.522 \text{ g}$</p> <p>$\frac{0.522}{82.68} \times 100 = 0.631\%$</p> <p>✓✓✓✓</p> <p>percentage of ethanedioic acid = <u>0.631%</u> % [6]</p>
		Total	7	
13 4	i	<p>Phenol ✓</p> <p>Amide ✓</p> <ul style="list-style-type: none"> IGNORE attempt to classify amide, e.g. secondary 	2	<p>IF > 2 functional groups are shown,</p> <ul style="list-style-type: none"> Mark 2 groups ONLY Mark incorrect groups first <p>Treat carbonyl with aldehyde OR with ketone as one functional group, i.e.</p> <ul style="list-style-type: none"> carbonyl, aldehyde carbonyl, ketone carbonyl <p>IGNORE aryl OR alkyl group e.g. benzene, phenyl, aryl, arene, methyl</p> <p>IGNORE hydroxyl/hydroxy</p> <p>Examiner's Comments</p> <p>This part assessed knowledge of functional groups and proved to be a very good discriminator. Able candidates usually identified the phenol and amide functional groups, with 'secondary amide' also seen.</p> <p>In Exemplar 9, the candidate has identified the correct functional groups. The candidate's working by circling the functional groups in</p>



			<p>the structure shows good examination technique, helping the candidate to arrive at the correct conclusion.</p> <p>The phenol group was often incorrectly identified as an alcohol and the amide group as a combination of 'amine', 'ketone', 'keytone' or 'carbonyl'. Neutral responses such as 'hydroxyl' and 'benzene' were ignored.</p> <p>Candidates need to be careful that they do not present an extensive list of many functional groups in the hope that the correct groups are amongst them, as shown in Exemplar 10. Incorrect groups are marked first.</p> <p>Exemplar 9</p> <p>(i) Name the functional groups present in paracetamol.</p> <p>phenol ✓ amide ✓ [2]</p> <p>Exemplar 10</p> <p>Name the functional groups present in paracetamol.</p> <p>phenol ✓ benzene ✓ alkyl amine ✓ [2]</p>
	ii	<p>Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.</p> <p>Level 3 (5-6 marks) A correct calculation of the mass of 4-nitrophenol. AND Identifies the reagents AND intermediate. AND A detailed description of most purification steps.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3-4 marks) Calculates the mass of 4-nitrophenol with</p>	<p>Indicative scientific points may include: Calculation of mass of 4-nitrophenol Using moles</p> <ul style="list-style-type: none"> $n(\text{paracetamol}) = \frac{5.00}{151} = 0.0331 \text{ (mol)}$ $n(4\text{-nitrophenol}) = 0.0331 \times \frac{100}{40} = 0.0828 \text{ (mol)}$ Mass of 4-nitrophenol = $139 \times 0.0828 = 11.5 \text{ g}$ <p>ALLOW 11.4–11.6 for small slip/rounding</p> <p>Using mass</p> <ul style="list-style-type: none"> Theoretical mass paracetamol = $5.00 \times \frac{100}{40} = 12.5 \text{ g}$ Theoretical $n(4\text{-nitrophenol}) = \frac{12.5}{151} = 0.0828 \text{ (mol)}$ Mass of 4-nitrophenol = $139 \times 0.0828 = 11.5 \text{ g}$



	<p>some errors AND suggests reagents and intermediate with some omissions. OR Calculates the mass of 4-nitrophenol with some errors AND describes some purification steps, with some detail. OR Suggests reagents and intermediate with some omissions AND describes some purification steps, with some detail.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1-2 marks) Attempts to calculate the mass of 4-nitrophenol OR Suggests reagents OR intermediate but may be incomplete OR Describes few purification steps.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks No response or no response worthy of credit.</p>	<p>NOTE: Incorrect inverse ratio of $\frac{100}{40}$</p> <p>gives:</p> <ul style="list-style-type: none"> $0.0331 \times \frac{40}{100} = 0.0132$ (mol) Mass = $139 \times 0.0132 = 1.84$ g <p><u>Reagents and intermediate</u></p> <ul style="list-style-type: none"> Reagents: Sn + (conc) HCl (then NaOH) Intermediate: 4-aminophenol or structure <p><u>Purification</u></p> <ul style="list-style-type: none"> Dissolve impure solid in minimum volume of hot solvent Cool solution and filter solid Scratch with glass rod Wash with cold solvent/solvent and dry <p>Examples of detail in bold (NOT INCLUSIVE)</p> <p>NOTE: 'Recrystallisation' on its own is NOT a detailed description</p> <p><u>Examiner's Comments</u></p> <p>This part assessed practical aspects of a two-stage organic synthesis. Overall, candidates responded well, and this part was discriminating. Many candidates produced well-structured responses although lower ability candidates do have problems with constructing a cohesive response.</p> <p>Most candidates identified the correct reagents (Sn and concentrated HCl) and the intermediate (4-aminophenol), which was usually shown as its structure.</p> <p>Able candidates usually showed that 11.5 g of 4-nitrophenol is needed for the synthesis. A common error used the 'inverse percentage' ratio of 40/100, resulting in an incorrect mass of 1.84 g. Candidates are recommended to check whether a calculated answer looks sensible. Looking at the structures and with a percentage yield of 40%, 1.84 g does not look</p>
--	---	---



to be enough of the starting chemical.

Some lower ability candidate responses assumed that 5.00 g was 40% of the required mass and responded with $5.00 \times 100/40 = 12.5$ g.

There were some good descriptions of purification, although finer details such as using a minimum volume of hot solvent, washing with cold solvent, and drying) were often omitted. Candidates needed to respond with more than just 'recrystallisation'.

In the purification, common errors were showing the correct steps but in the wrong order and use of a drying agent such as CaCl_2 (confusion with part of the purification of an organic liquid). These candidates seemed unaware that adding a solid drying agent to an organic solid would result in impure paracetamol rather than purifying.

Exemplar 11 shows an excellent response that addresses all aspects of the problem.

In comparison, Exemplar 12 is much less detailed: concentrated HCl has not been shown as a reagent for step 1, the candidate has not shown that they know how to carry out a percentage yield calculation, and the purification is confused, and lacks detail.

Exemplar 11

(11) A chemist prepares a pure solid sample of paracetamol from 4-nitrophenol in two stages:

4-nitrophenol $\xrightarrow{\text{Stage 1}}$ Intermediate $\xrightarrow{\text{Stage 2, } \text{CH}_3\text{COOC-CH}_3}$ paracetamol

$\text{C}_6\text{H}_5\text{NO}_3$ $\text{C}_8\text{H}_9\text{NO}_2$

Describe a two-stage synthesis of 5.00g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%.

In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol. [13]

$\text{HO-C}_6\text{H}_4\text{-NO}_2 + 6[\text{H}] \xrightarrow{\text{Sn, conc. HCl}} \text{HO-C}_6\text{H}_4\text{-NH}_2 + 2\text{H}_2\text{O}$

$\text{HO-C}_6\text{H}_4\text{-NH}_2 + \text{H}_3\text{C-CO-O-CO-CH}_3 \rightarrow \text{HO-C}_6\text{H}_4\text{-NH-CO-CH}_3 + \text{HCl}$

molar mass paracetamol = 151 g mol⁻¹

mass in 5g : 151 = 0.0331 mol

mass required = 0.0331 ÷ 0.4 = 0.08275 mol

mass of 4-nitrophenol required = 0.08275 mol

mass of 4-nitrophenol required = 0.08275 × 139 = 11.5g

To purify the paracetamol, filter the remaining solution under reduced pressure using Buchner apparatus. Dissolve the remaining solid in the minimum amount of hot solvent and filter again. Cool the remaining solution and filter with cold water. Wash the remaining solid with cold solvent.

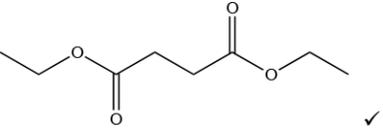
Additional answer space if required.

and leave to dry.



				<p>Exemplar 12</p> <p>In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol. 6 12</p> <p>4-nitrophenol is reacted with reduced with (Sn) in presence of conc acid and forms 4-phenylamine under high temperature</p> <p style="text-align: center;"> </p> <p>$\frac{100}{140} \times 5.00 = 12.5g$ from the beginning is required</p> <p>A pure sample of paracetamol was obtained by crystallisation. The impure solution was heated with a Bunsen burner and stirred until crystals start forming. After formation in was left to cool and an oven was used to evaporate any water left.</p>
		Total	8	
13 5	i	Titration ✓	1	<p>IGNORE type of titration</p> <p><u>Examiner's Comments</u></p> <p>Candidates found this part difficult and only higher ability candidates identified that a titration could easily determine the concentration of succinic acid.</p> <p>The answers seen covered most of the techniques encountered in the course. Candidates should consider the information provided in a practical context to arrive at an informed response rather than what sometimes seemed to be a guess.</p>
	ii	$(\text{CH}_2\text{COOH})_2 + 2\text{C}_2\text{H}_5\text{OH} \rightleftharpoons (\text{CH}_2\text{COOC}_2\text{H}_5)_2 + 2\text{H}_2\text{O} \checkmark$	1	<p>ALLOW → instead of ⇌ sign</p> <p>ALLOW molecular formulae or hybrid formulae</p> <p><i>Structures provided on QP</i></p> <p>e.g. $\text{C}_4\text{H}_6\text{O}_4 + 2\text{C}_2\text{H}_6\text{O} \rightleftharpoons \text{C}_8\text{H}_{14}\text{O}_4 + 2\text{H}_2\text{O}$</p> <p><u>Examiner's Comments</u></p> <p>Candidates were required to derive the equation from which the supplied K_c expression had been written.</p> <p>Overall, this part was answered well but some candidates struggled with the brackets or used CH_2COOH_2 for succinic acid.</p>



	iii		1	<p>IGNORE displayed formulae</p> <p>Examiner's Comments</p> <p>This part discriminated extremely well with many candidates finding it difficult to convert the bracketed structural formula into a skeletal formula. Common errors were drawing of the mono-ester or omitting a carbon atom in the centre of the structure.</p> <p>Even when incorrect, most attempted answers were skeletal formulae.</p>
	iv	<p>Volume cancels OR Same number of moles on each side of equation ✓</p>	1	<p>ALLOW units cancel</p> <p>ALLOW (sum of) balancing numbers/coefficients on each side of equation are the same OR same number of (moles of) reactants and products</p> <p>IGNORE volume is the same; K_c has no units</p> <p>Examiner's Comments</p> <p>Many candidates did not seem to realise that the supplied equation used moles, not concentrations. Those who did often stated that the mole representation could be used because the volume was the same for all. Of those who went on to state that the volume would cancel, only a few explained why that was true in this particular case.</p> <p>This challenging part discriminated very well. The best responses showed the units as n/V in the expression and showed that the volumes cancel.</p>
	v	<p>Moles of equilibrium products 1 mark</p> <p>$n((\text{CH}_2\text{COOC}_2\text{H}_5)_2) = 0.0300 \text{ (mol)}$ AND $n(\text{H}_2\text{O}) = 0.0600 \text{ (mol)} \checkmark$</p> <p>Moles of C₂H₅OH 1 mark</p> <p>$n(\text{C}_2\text{H}_5\text{OH}) = 0.150 - 0.060 = 0.0900 \text{ (mol)} \checkmark$</p>	3	<p>ALLOW ECF</p>



		<p>K_c calculated 1 mark</p> $= \frac{0.03 \times 0.06^2}{0.02 \times 0.09^2} = 0.667 \text{ OR } 0.67 \checkmark$ <p>NOTE: 0.02 must be used for n(succinic acid)</p>		<p>ALLOW 0.66, 0.666, etc. (2 SF and more) <i>Treated as meaning 0.6 recurring</i></p> <p>ALLOW 2/3 IGNORE any units</p> <p><u>Examiner's Comments</u></p> <p>Overall, this part discriminated well with many candidates obtaining the correct answer of 0.67. Common errors included a one significant figure answer of 0.6 or 0.7 and 0.375, by using 0.12 mol instead of 0.09 mol for the moles of ethanol.</p> <p>Many successful answers were well-presented and included a table of initial and final values. This gave a systematic way of deriving the equilibrium moles.</p>
		Total	7	
13 6		C	1	<p><u>Examiner's Comments</u></p> <p>Candidates found this question difficult with comparatively few obtaining the correct response of C. Many candidates selected B instead, the number of CO₂ or O₂ molecules, and not the number of O atoms. Good advice is to read the question carefully and to underline any key features.</p>
		Total	1	
13 7		B	1	<p><u>Examiner's Comments</u></p> <p>Nearly all candidates responded with the correct response of B.</p>
		Total	1	
13 8		C	1	<p><u>Examiner's Comments</u></p> <p>This part discriminated well, with most able candidates selecting the correct answer of C. A sizeable number selected B, presumably by not considering the 2:1 stoichiometric ratio in the equation.</p>
		Total	1	
13 9		D	1	<p><u>Examiner's Comments</u></p> <p>Most candidates selected A or D, with D</p>



					being the correct option. Presumably, A was chosen by halving the '8' in C ₄ H ₈ without considering that each H ₂ O molecule contains two H atoms. The successful answer of D usually resulted from the candidate constructing equations.
			Total	1	
14 0			A	1	<p><u>Examiner's Comments</u></p> <p>Many candidates added H atoms to the structure to aid their choice. Most candidates selected the correct response of A, with a sizeable number selecting B (by adding two H atoms where the two rings join).</p>
			Total	1	
14 1	a	i	<p>Oxidised AND (Mg) transfers/loses/donates 2 electrons ✓</p> <p style="text-align: right;">2 essential</p>	1	<p>ALLOW Mg loses 6 electrons: 3 Mg in equation ALLOW Mg → Mg²⁺ + 2e⁻</p> <p>IGNORE oxidation numbers (even if wrong)</p> <p><u>Examiner's Comments</u></p> <p>Despite the question clearly asking for a response in terms of the number of electrons transferred, most candidates answered in terms of oxidation number changes. Candidates are recommended to read the question and to answer in terms of its requirements. Underlining 'number of electrons' may have helped candidates to answer the question that had been set.</p>
		ii	<p>FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 2.26 (3 SF) award 3 marks</p> <p>-----</p> $n(\text{H}_3\text{PO}_4) = \frac{1.24 \times 50.0}{1000} = 0.062(0) \text{ (mol)} \checkmark$ $n(\text{Mg}) = \frac{3}{2} \times 0.062(0) = 0.093(0) \text{ (mol)} \checkmark$ <p>mass of Mg = 0.0930 × 24.3 = 2.26 (g) ✓</p> <p style="text-align: right;">3 SF required</p>	3	<p>At least 3SF needed throughout BUT ALLOW no trailing zeroes (e.g. 0.062 for 0.0620)</p> <p>ALLOW ECF from $n(\text{H}_3\text{PO}_4)$</p> <p>ALLOW ECF from $n(\text{Mg})$</p> <p>-----</p> <p>COMMON ERRORS for 2 marks 3:2 ratio omitted → $n(\text{Mg}) = 0.062(0)$ → 1.51</p>



			<p>(g) Inverted 2:3 ratio → $n(\text{Mg}) = 0.0413 \rightarrow 1.00$ (g)</p> <p>Examiner's Comments</p> <p>Most candidates are competent at answering questions based on the mole. Almost all candidates were able to calculate the amount of H_3PO_4 as 0.062 mol. Candidates then needed to use the 2:3 mole stoichiometric ratio to show that 0.093 mol of Mg reacts, which has a mass of 2.26 g to the required 3 significant figures. The commonest errors were use of the inverse 3:2 ratio to obtain 1.00 g Mg, or to omit the ratio to obtain 1.51 g Mg, as shown in the exemplar. Candidates are advised to show clear working so that credit can be awarded for such responses by applying error carried forward.</p> <p>Exemplar 1</p> <p>(ii) The student plans to add magnesium to 50.0 cm^3 of 1.24 mol dm^{-3} H_3PO_4. Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid. Give your answer to three significant figures.</p> <p>$50 \text{ cm}^3 = 0.05 \text{ dm}^3$ $1.24 \times 0.05 = 0.062 \text{ mol}$ $0.062 \times 24.3 = 1.5066$ mass of Mg = 1.51 g [3]</p>
	iii	<p>Separation of solid</p> <p>Filter to obtain solid/precipitate ✓ <i>Requires realisation that solid is filtered off.</i> <i>Solid may be stated within in 'removal of water'</i></p> <p>Removal of water</p> <p>Dry (solid) OR Evaporate (water/solution/liquid) ✓</p>	<p>ALLOW Removal of water</p> <p>Evaporate/ distil water/solution/liquid ✓</p> <p>IGNORE 'distil' if product OR H_2 is distilled</p> <p>Collection of remaining solid ✓</p> <p><i>Requires realisation that solid remains</i> IGNORE 'Leave to crystallise' (<i>already solid</i>)</p> <p>Examiner's Comments</p> <p>Candidates often struggle with questions based on practical work. There were many random responses to this question, with relatively few candidates identifying that solid magnesium phosphate could be obtained by filtration, followed by drying.</p>



	iv	<p>Formula</p> <p>MgO OR Mg(OH)₂ OR MgCO₃ OR soluble Mg salt ✓</p> <p>Equation</p> <p>3MgO + 2H₃PO₄ → Mg₃(PO₄)₂ + 3H₂O OR 3Mg(OH)₂ + 2H₃PO₄ → Mg₃(PO₄)₂ + 6H₂O OR 3MgCO₃ + 2H₃PO₄ → Mg₃(PO₄)₂ + 3CO₂ + 3H₂O</p>	2	<p>In equation: NO ECF from incorrect formula ALLOW multiples IGNORE state symbols (even if incorrect)</p> <p>Soluble Mg salts include MgCl₂, MgSO₄, Mg(NO₃)₂, MgBr₂, MgI₂ If unsure, check with TL e.g. 3MgCl₂ + 2H₃PO₄ → Mg₃(PO₄)₂ + 6HCl</p> <p>Examiner's Comments</p> <p>Candidates were expected to identify a suitable reagent for this reaction, with most choosing magnesium oxide, hydroxide or carbonate. Credit was also given for using a soluble magnesium salt such as its sulfate, chloride or nitrate. The correct equation often followed, but errors sometimes appeared in the form of incorrect formulae, such as MgOH for magnesium hydroxide. The exemplar shows a good clear response, using MgO as the reagent.</p> <p>Exemplar 2 (iv) Magnesium phosphate can also be prepared by reacting phosphoric acid with a compound of magnesium. Choose a suitable magnesium compound for this preparation and write the equation for the reaction. Formula of compound MgO ✓ Equation 3MgO + 2H₃PO₄ → Mg₃(PO₄)₂ + 3H₂O [2]</p>
	b i	<p>FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 315 (cm³) award 4 marks</p> <p>-----</p> <p>Amount of PH₃ $n(\text{PH}_3) = \frac{3.20 \times 10^{-2}}{4}$ OR 8(.00) × 10⁻³ (mol) ✓</p> <p>Unit conversions</p> <p><i>p</i> conversion → Pa = 100 × 10³ (Pa) AND <i>T</i> conversion → K = 473 (K) ✓</p> <p>Evidence of use of rearranged gas equation</p>	4	<p>If there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW ECF throughout</p> <p>-----</p> <p>Common Errors (3 marks)</p> <p>Use of $n(\text{H}_3\text{PO}_4) = 3.20 \times 10^{-2}$ (Very common) $V = \frac{3.2(0) \times 10^{-2} \times 8.314 \times 473}{100 \times 10^3} \times 10^6$ = 1258.40704 cm³ (1260 to 3 SF)</p> <p>No temperature conversion from °C to K</p>



$$\text{OR } V = \frac{nRT}{p}$$

$$\text{OR } V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 473}{100 \times 10^3}$$

$$\text{OR } V = 3.15 \times 10^{-4} \checkmark$$

$$\text{Calculator: } = 3.1460176 \times 10^{-4}$$

V conversion of m³ → cm³ ✓

$$V = 3.15 \times 10^{-4} \times 10^6 = 315 \text{ cm}^3 \checkmark$$

Calculator from unrounded cm³: 314.60176 cm³

Requires 3 OR MORE SF, correctly rounded

ALLOW use of R = 8.31 → 314.4504 → 314 to 3SF

$$V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 200}{100 \times 10^3} \times 10^6$$

$$= 133 \text{ cm}^3$$

No p conversion from kPa to Pa

$$V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 473}{100} \times 10^6$$

$$= 315000 \text{ cm}^3$$

No volume conversion from m³ to cm³

$$V = 3.15 \times 10^{-4}$$

IGNORE use of 24/24000 for molar volume e.g.

$$3.2(0) \times 10^{-3} \times 24000 = 768 \text{ scores zero}$$

$$8(.00) \times 10^{-3} \times 24000 = 292 \text{ scores 1st mark only}$$

Examiner's Comments

Almost all candidates realised that the calculation required the ideal gas equation. Most candidates correctly rearranged the equation and used the data from the question to obtain a value for the volume of phosphine. The most common errors were with conversion of units into Pa and m³. It is recommended that candidates learn how to carry out these conversions. In their calculations, many candidates used the amount of phosphoric acid, 3.20×10^{-3} mol, rather than 8.00×10^{-3} mol of phosphine, obtaining a volume of 1258 cm³. Error carried forward ensured that 3 of the available 4 marks could be credited, provided that the working was clear. The exemplar shows such a response.

$$\text{Answer} = 315 \text{ cm}^3$$

Exemplar 3



				<p>(b) Phosphine, PH_3, is a gas formed by heating phosphorous acid, H_3PO_3, in the absence of air.</p> $4\text{H}_3\text{PO}_3(\text{s}) \rightarrow \text{PH}_3(\text{g}) + 3\text{H}_2\text{PO}_4(\text{s})$ <p>(i) 3.20×10^{-2} mol of H_3PO_3 is completely decomposed by this reaction.</p> <p>Calculate the volume of phosphine gas formed, in cm^3, at 100 kPa pressure and 200°C.</p> <p><i>Handwritten solution:</i></p> $pV = nRT$ <p>Annotations: $p = 100$ (kPa), $V = \text{dm}^3$, $n = 3.2 \times 10^{-2}$ (mol), $R = 8.314$ (J mol⁻¹ K⁻¹), $T = 200 + 273 = 473$ (K).</p> $100 \times V = (3.2 \times 10^{-2}) \times 8.314 \times 473$ $100 \times V = 125.840704$ $V = 1.25840704$ $= 1.26 \text{ dm}^3 \times 1000$ $= 1258.41 \text{ cm}^3$ <p>volume of $\text{PH}_3 = \dots 1258.41 \text{ cm}^3$ [4]</p>
	ii	$4\text{PH}_3 + 8\text{O}_2 \rightarrow \text{P}_{4010} + 6\text{H}_2\text{O} \checkmark$	1	<p>ALLOW multiples</p> <p>Examiner's Comments</p> <p>Most candidates were able to write a correctly balanced equation for this reaction.</p>
		Total	13	
14 2	i	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF $\Delta_r H = -457$ OR -458 (kJ mol^{-1}) award 4 marks</p> <p>IF $\Delta_r H = \pm 229$ OR 457 (kJ mol^{-1}) award 3 marks</p> <p>-----</p> <p>Energy released in J OR kJ</p> $= 25.0 \times 4.18 \times 28.0 = 2926 \text{ (J) OR } 2.926 \text{ (kJ)} \checkmark$ <p>Correctly calculates $n(\text{AgNO}_3)$</p> $= 0.512 \times \frac{25.0}{1000} = 1.28 \times 10^{-2} \text{ (mol)} \checkmark$ <p>ΔH per mole AgNO_3 in kJ AND 3 SF</p> <p>Answer MUST divide energy by $n(\text{AgNO}_3)$</p> $\pm \frac{2.926}{1.28 \times 10^{-2}} = \pm 228.59375$ $= \pm 229 \text{ (kJ)} \checkmark$ <p>3 SF needed Sign NOT needed</p> <p>ΔH for 2 mol AgNO_3 AND – sign AND 3 SF</p> $\Delta H_r = 2 \times -228.59375 = -457 \text{ (kJ mol}^{-1}\text{)}$	4	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ALLOW ECF throughout</p> <p>-----</p> <p>ALLOW 2930 J OR 2.93 kJ</p> <p>DO NOT ALLOW < 3 SF</p> <p>IGNORE any sign and units</p> <p><i>i.e. ALLOW correctly calculated number in J OR kJ</i></p> <p>-----</p> <p>Alternative approach using 1 mol Mg</p> <p>Energy released = 2926 (J) OR 2.926 (kJ) \checkmark</p> $n(\text{AgNO}_3) = 1.28 \times 10^{-2} \text{ (mol)} \checkmark$ $n(\text{Mg}) = \frac{1.28 \times 10^{-2}}{2} = 6.4 \times 10^{-3} \text{ (mol)} \checkmark$ $\Delta H_r = \frac{2.926}{6.4 \times 10^{-3}} = -457 \text{ (kJ mol}^{-1}\text{)}$ <p>– sign AND 3 SF needed</p> <p>Examiner's Comments</p>



		<p>OR $2 \times -229 = -458 \text{ (kJ mol}^{-1}\text{)} \checkmark$</p>	<p>Candidates are well-versed with the relationship $q = mc\Delta T$ and most were able to calculate that 2.926 kJ of energy was released in this reaction. It was also common to see the amount of AgNO_3 correctly calculated as $1.28 \times 10^{-3} \text{ mol}$. Candidates were expected to determine the amount of energy released from 1 mol AgNO_3 as 229 kJ and finally to multiply this value by 2 for the molar quantities in the equation to match the 'enthalpy change of reaction'. It was common to see -229 given as the final answer but this was rarely multiplied by 2. The question also required the final answer to be given to an appropriate number of significant figures. Many candidates seemed to be unaware that this reflects the least significant figure provided in the data, in this case 3 significant figures. The exemplar shows a typical response for 3 of the available 4 marks. Many omitted the negative sign in their ΔH value to consider the exothermicity of the reaction. Candidates are also advised to only round at the end of a multi-step calculation. Rounding of intermediate values introduces rounding errors in the final answer.</p> <p>Answer = -457 kJ mol^{-1}</p> <p>Exemplar 4</p> <p>(i) Calculate ΔH, in kJ mol^{-1}, for the reaction shown in equation 23.1.</p> <p>Give your answer to an appropriate number of significant figures.</p> <p>Assume that the density and specific heat capacity, c, of the solution are the same as for water and that all the aqueous silver nitrate has reacted.</p> <p>$c = 4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$ density = 1.00 g cm^{-3} $Q = mc\Delta T$</p> <p>$\Delta T = 28$ density = 1.00 g cm^{-3} $n = \frac{m}{M_r}$</p> <p>$Q = 25 \times 4.18 \times 28$ $n = \frac{25}{1000} \times 0.512$</p> <p>$Q = 2926 \text{ J}$ $n = 0.0128$</p> <p>$Q = 2.926 \text{ kJ}$</p> <p>$\frac{2.926}{0.0128} = 228.60 \text{ } 228.59375$</p> <p>$\Delta H = \dots 229 \dots \text{ kJ mol}^{-1} [4]$</p> <p style="text-align: center;">✓ ✓ ✓</p>
	ii	<p>$\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s}) \checkmark$</p> <p>State symbols required</p> <p>White precipitate AND $\text{AgNO}_3/\text{Ag}^+$ NOT ALL reacted</p> <p>OR</p>	<p>2</p> <p>ALLOW $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$</p> <p>Observation needs to be linked to conclusion</p> <p>Examiner's Comments</p>



		NO white precipitate AND AgNO ₃ /Ag ⁺ ALL reacted ✓		Most candidates recognised that silver nitrate and chloride ions react together to form a white precipitate, but many did not make the link between this observation and whether any silver nitrate was left unreacted. Many candidates did not give a correct equation, with missing or incorrect state symbols being common. This question discriminated extremely well.
		Total	6	
14 3	a	<p>Structural isomers: <i>1 mark</i></p> <p>Different structural formulae AND same molecular formula ✓</p> <p>Common molecular formula: <i>1 mark</i></p> <p>C₅H₁₂ for all 3 hydrocarbons ✓</p> <p>Boiling point and branching:</p> <p style="text-align: center;"><i>1 mark</i></p> <p>Boiling point decreases with more branching</p>	5	<p>For 'structural': ALLOW different structure OR different displayed/ skeletal formula</p> <p>DO NOT ALLOW any reference to spatial/space/3D</p> <p>Same formula is not sufficient (no 'molecular')</p> <p>Different arrangement of atoms is not sufficient (no 'structure'/'structural')</p> <p>ALLOW 5 carbons and 12 hydrogens</p> <p>ALLOW for 2 marks: Different structural formulae AND same molecular formula ✓ of C₅H₁₂ ✓</p> <p>Comparisons needed throughout ORA throughout</p> <p>ALLOW comparison between any alcohols, e.g. A is least branched and has highest b pt C is most branched and has lowest b pt</p> <p>ALLOW induced dipole(–dipole) interactions IGNORE van der Waals'/vdw forces ALLOW SA for surface area</p> <p>ALLOW 'harder to overcome intermolecular forces' ALLOW more energy to separate the molecules</p> <p>IGNORE just 'bonds'</p>



		<p>OR more methyl/alkyl groups/side chains OR shorter carbon chain ✓</p> <p>Branching and London forces: 1 mark</p> <p><i>Could be seen anywhere within response</i> More branching gives less (surface) contact</p> <p>AND fewer/weaker London forces ✓</p> <p>Energy and intermolecular forces: 1 mark</p> <p>Less energy to break London forces/ intermolecular forces/intermolecular bonds/ ✓</p>		<p>intermolecular/London forces required</p> <p>Examiner's Comments</p> <p>This question discriminated well and resulted in a full range of marks. Most candidates were aware that structural isomers have different structural formulae but the same molecular formulae. It was common though for candidates to refer to different arrangements of atoms in space, clearly confusing with stereoisomerism. The best candidates used the structures (as in the question) to show that the common molecular formula was C₅H₁₂. Candidates were expected to link the amount of surface contact between molecules with induced dipole–dipole forces or London forces. 'Contact' or the name of the intermolecular forces was often omitted. Finally, candidates were expected to link the amount of branching to the strength of the intermolecular forces and the energy needed to change state. Lower ability candidates often let themselves down by being unable to construct a well-reasoned response. There was often a gulf between the clear responses of able candidates and those of lower ability candidates.</p>				
	b	Enter text here.	Enter text here.	Enter text here.				
	i	Radical substitution ✓	1	<p>ALLOW Free radical substitution</p> <p>Examiner's Comments</p> <p>Most candidates identified this reaction as radical substitution.</p>				
	ii	<table border="1"> <thead> <tr> <th>A</th> <th>B</th> </tr> </thead> <tbody> <tr> <td>3 ✓</td> <td>4 ✓</td> </tr> </tbody> </table>	A	B	3 ✓	4 ✓	2	<p>Examiner's Comments</p> <p>Most candidates achieved at least one mark, particularly for isomer A. Successful candidates often drew structures of the isomers alongside the table to help with their response.</p>
A	B							
3 ✓	4 ✓							



				<p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>IGNORE molecular formula</p> <p>ALLOW multiples, e.g. $2C_5H_{12} + 6Cl_2 \rightarrow 2C_5H_9Cl_3 + 6HCl$</p> <p>Examiner's Comments</p> <p>Many candidates correctly drew the structure of compound D but comparatively few were able to construct a correct equation. For this equation, candidates needed to apply their knowledge and understanding of monosubstitution of alkanes to substitution of three H atoms by three Cl atoms. This task proved to be one of the most difficult questions on this paper. The exemplar shows an excellent response. The candidate has drawn a trisubstituted structure that fits the molar mass of 175.5 g mol^{-1} and a correct equation for its formation. Many attempts at this equation showed H_2 as the second product rather than HCl.</p> <p>Exemplar 6</p> <p>(iii) The reaction of compound A with excess chlorine forms a compound D, which has a molar mass of 175.5 g mol^{-1}.</p> <p>Draw a possible structure for compound D and write the equation for its formation from compound A. Use molecular formulae in the equation.</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 10px auto;"> </div> <p>Equation $C_5H_{12} + 3Cl_2 \rightarrow C_5H_9Cl_3 + 3HCl$</p>
		iii	<p>Structure of D</p> <p>Structure of a trichloro isomer of A, e.g.</p> <p>ALLOW any trichloro isomer of A CHECK carefully</p> <p>Equation</p> <p>$C_5H_{12} + 3Cl_2 \rightarrow C_5H_9Cl_3 + 3HCl$ ✓ Molecular formulae required</p> <p>NO ECF from incorrect structure of D</p>	2
		Total		10
14 4		A		1 (AO 2.4)
		Total		1



14 5	a	<p>FIRST, CHECK ANSWER IF answer = 231 000, award 2 marks</p> <hr/> <p>n(C₃H₈)</p> $n(\text{C}_3\text{H}_8) = \frac{42.0 \times 10^3}{24.0} \quad \text{OR} \quad \frac{42.0 \times 10^6}{24\,000} \quad \text{OR} \quad 1750 \quad (\text{mol}) \checkmark$ <p>Mass of CO₂ mass CO₂ = 3 × 1750 × 44</p> $= 231\,000 / 2.31 \times 10^5 \text{ (g)} \checkmark$ <p>ALLOW 2 SF, e.g. 230 000</p>	<p>2</p> <p>AO 2.2</p> <p>AO 2.6</p>	<p>ALLOW use of ideal gas equation with a sensible temperature (20–25°C) and pressure (100/101 kPa) At 20°C and 100 kPa,</p> $n(\text{C}_3\text{H}_8) = \frac{100 \times 10^3 \times 42.0}{8.314 \times 293} = 1724\dots (\text{mol})$ <p>→ ~ 227586 (g) (dependent on roundings)</p> <p>At 25°C and 100 kPa,</p> $n(\text{C}_3\text{H}_8) = \frac{100 \times 10^3 \times 42.0}{8.314 \times 298} = 1695\dots (\text{mol})$ <p>→ ~ 223767 (g) (dependent on roundings)</p> <p>ALLOW use of 8.31 for R</p> <p>ALLOW ECF from n(C₃H₈) -----</p> <p>----- Common errors from 24.0 dm³</p> <p>231 → 1 mark <i>No conversion of m³ to dm³</i></p> <p>0.231 → 1 mark <i>Confusion of cm³ and dm³</i></p> <p>77 000 → 1 mark <i>No 3 × for CO₂</i></p> <p><u>Examiner's Comments</u></p> <p>This part required candidates to work out the amount in moles of propane that combusted, followed by a calculation of the volume of CO₂.</p> <p>The initial mole calculation required candidates to first convert the volume of 42.0 m³ into dm³ or cm³. A correct calculation shows that 1750 mol of propane was combusted. Many struggled with the unit conversion, with 0.175 and 1.75 × 10⁻³ often being seen. This value then needed to be multiplied by 3 (from the stoichiometry of the equation) and 44 to produce 231,000 g. Here, ×3 was sometimes omitted.</p> <p>Some candidates ignored RTP in the question and used the ideal gas equation to calculate the moles of propane. This approach was acceptable provided that sensible values had been chosen for the conditions at room temperature and pressure (e.g. 298K, 293K, 100 kPa, 101 kPa).</p>
---------	---	--	--------------------------------------	--



				Candidates are advised to practice volume unit conversions – important for any calculation involving gases.
	b	<p>FIRST, CHECK ANSWER IF answer = 9.03×10^{22}, award 2 marks</p> <p>-----</p> $n(\text{P}_2\text{O}_5) = \frac{4.26}{142.0} \quad \text{OR } 0.03(00) \text{ (mol)} \checkmark$ <p>O atoms = $5 \times 0.0300 \times 6.02 \times 10^{23}$</p> <p>= $9.03 \times 10^{22} \checkmark$</p> <p>Minimum 3 SF required</p>	2 AO 2.2	<p>Alternative approach</p> $n(\text{O atoms}) = \frac{4.26}{142.0} \times 5 = 0.15 \checkmark$ <p>O atoms = $0.15 \times 6.02 \times 10^{23} = 9.03 \times 10^{22} \checkmark$ ALLOW ECF from incorrect $n(\text{P}_2\text{O}_5)$ ALLOW use of 6.022×10^{23}</p> <p>-----</p> <p>Common error 1.806×10^{22} OR $1.81 \times 10^{22} \rightarrow$ 1 mark No $\times 5$</p> <p>Examiner's Comments</p> <p>This part required candidates to initially work out the amount in moles of P_2O_5 in 4.26 g of P_2O_5, followed by multiplication by 5 (for O) and the Avogadro constant to produce 9.03×10^{22} atoms.</p> <p>The initial moles calculation proved to be a relatively easy mark which most candidates were awarded. Many then struggled, sometimes omitting the $\times 5$ factor to account for the O atoms, producing the common incorrect answer of 1.806×10^{22}.</p>
		Total	4	
14 6	i	$4\text{Pb}_2\text{O}_3 + 3\text{CH}_4 \rightarrow 8\text{Pb} + 3\text{CO}_2 + 6\text{H}_2\text{O}$ <p>OR</p> $\text{Pb}_2\text{O}_3 + \text{CH}_4 \rightarrow 2\text{Pb} + \text{CO} + 2\text{H}_2\text{O}$ <p>OR</p> $2\text{Pb}_2\text{O}_3 + 3\text{CH}_4 \rightarrow 4\text{Pb} + 3\text{C} + 6\text{H}_2\text{O} \checkmark$	1 AO 2.6	<p>ALLOW multiples</p> <p>IGNORE state symbols</p> <p>Examiner's Comments</p> <p>This equation proved to be very testing and only a minority of candidates were able to write a balanced equation for this reaction forming Pb, CO_2 and H_2O. Many different and implausible products were seen such as O_2, H_2, and CH_3OH.</p>
	ii	<p>ONE Safety issue AND precaution \checkmark From:</p> <p>Safety issue: Compounds may be toxic/poisonous/flammable</p>	1 AO 3.3	<p>IGNORE use safety glasses, lab coat (<i>in question</i>) and tying hair back, safety screen</p> <p>Definite safety issue needed.</p>



		<p>AND Precaution: Use a fume cupboard/good ventilation ----- Safety issue: Lead (compounds) is/are toxic/poisonous AND Precaution: Wear gloves ----- Safety issue: Methane is flammable AND Precaution: Keep away from flame -----</p>	<p>Not just 'harmful' OR dangerous (Too vague).</p> <p>FOR OTHER SAFETY ISSUES AND PRECAUTIONS, CONTACT TEAM LEADER</p> <p><u>Examiner's Comments</u></p> <p>The mark scheme catered for a wide range of responses that were judged to be worthy of credit. Responses that form part of normal safe laboratory practice, such as keeping bags under benches, tying hair back, etc., were not given.</p> <p>Candidates were expected to identify a precaution for a chemical hazard. As with GCSE, general words to describe hazards, such as harmful and dangerous, were not given. Acceptable chemical hazards would include those encountered in hazard signs such as flammable (for methane) or toxic (for lead or lead compounds). The best responses suggested that naked flames should be kept away from flammable methane or that gloves should be worn when using toxic lead. Other suggested use of a fume cupboard or good ventilation when using flammable or toxic materials. Responses such as 'face masks' gained no credit.</p>
	iii	<p>Any 2 modifications ✓ ✓ from</p> <ol style="list-style-type: none"> 1. Heat to constant mass (Ensures all lead oxide has reacted) Spread/stir/break up lead oxide OR increase surface area 2. OR use powder rather than lumps (Ensures all lead oxide has reacted) Pass methane/inert gas/N₂ through tube as it cools 3. OR don't pass cold air (Prevents O₂ reacting with Pb) Use excess methane OR more methane 4. (Ensures all lead oxide has reacted) 	<p>ALLOW response that implies heating to constant mass, e.g. Heat again until the mass does not change</p> <p>IGNORE 'heat for longer' <i>Needs link to constant mass</i></p> <p>IGNORE 'weigh straight after heating'</p> <p>IGNORE idea of repeating the experiment/ taking an average/ getting concordant results / larger sample size, etc.</p> <p><u>Examiner's Comments</u></p> <p>For one modification, many candidates suggested heating to constant mass. A second modification proved to be elusive for many. Other acceptable modifications included using powdered lead oxide to increase the surface area, bubbling the escape gases through lime water to identify</p>



		<p>Bubble (escaping) gas through lime water</p> <p>5. (Ensures all lead oxide has reacted OR ensures all CO₂ has been produced).</p>		<p>when no more CO₂ was being produced in the reaction, and passing an inert gas through the apparatus during cooling to prevent re-oxidation of the lead from oxygen in the air.</p> <p>Some suggestions would have created safety issues, such as working in a closed system. A significant number of candidates suggested collecting the gases evolved and that the reaction was complete when the gas volume no longer increased. Presumably the suggestion came from practical experience of rates experiments involving gas collection. This is unfeasible though when there is a constant flow of methane gas.</p>
	iv	<p>Masses(/g): Pb : O 3.132 AND 0.322</p> <p>OR Mole ratios: $\frac{3.132}{207.2} : \frac{0.322}{16.0}$</p> <p>OR Mole ratios: 0.0151: 0.020125 ✓</p> <p>Empirical formula Pb₃O₄ (must come from masses) ✓</p>	2 AO 2.8×2	<p>NO ECF from incorrect masses</p> <p><u>Examiner's Comments</u></p> <p>Most candidates were able to work out the masses of Pb and O atoms in the lead oxide from the supplied experimental results, and to then attempt to find the molar ratio of Pb : O. The 1 : 1.33 ratio was not always identified and a significant number of candidates approximated this to PbO or Pb₂O₃ instead of scaling up the ratio to 3 : 4 to show that the formula is Pb₃O₄.</p>
		Total	6	
14 7	A		1 (AO 2.2)	<p><u>Examiner's Comments</u></p> <p>This question was quite well answered with many candidates calculating the Mr by multiplying the mass by Avogadro's number. This gave the answer as 16, which matches the Mr of CH₄, giving A as the correct answer. Option B provided a distractor as oxygen atoms have a relative mass of 16 whereas option B relates to O₂ molecules with a relative mass of 32. Some candidates got part way through the calculation and then appeared to choose an answer at random.</p>
		Total	1	



14 8		B	1 (AO 2.6)	<u>Examiner's Comments</u> This question was quite well answered with many candidates realising that the formula of the metal chloride was MCl_2 . The most reliable way of tackling the calculation was to calculate the mass of chlorine which reacted (the difference between the two given masses), working out the number of moles of chlorine and then calculating the Ar of the metal. This led them to identify the metal as calcium (option B). Some candidates took the long route by taking each option in turn, working out the number of moles and seeing which value matched the moles of chlorine. Candidates who chose incorrect answers could not complete all the calculation steps and appeared to choose one at random.
		Total	1	
14 9		C	1 (AO1.2)	
		Total	1	
15 0		D	1 (AO1.2)	<u>Examiner's Comments</u> This part discriminated extremely well. Many scripts showed clear working of the atom economy of each process, the usual result being the correct response of D. Candidates choosing an incorrect process (usually A), often showed no working suggesting the response was a guess. The advice here is obviously to work through calculations before choosing the answer.
		Total	1	