1. Three alcohols, **A**, **B** and **C**, are structural isomers with the molecular formula $C_5H_{12}O$.

A, **B** and **C** take part in combustion reactions.

Complete the equation for the complete combustion of $C_5H_{12}O$.

$C_5H_{12}O$ + ... **[2]**

2(a). This question is about the chemistry of compounds containing phosphorus.

Phosphine, PH_3, is a poisonous gas.

i. Phosphine reacts with oxygen gas to form phosphorus(V) oxide and water.

Write the equation for this reaction.

[1]

ii. Aqueous silver nitrate, $AgNO_3$, is reduced by PH_3.
The unbalanced equation is shown below.

Balance the equation and use oxidation numbers to explain why this is a redox reaction.

.... $AgNO_3$ + ... PH_3 + ... H_2O .... Ag + ... H_3PO_3 +........ HNO_3

Explanation

[3]

(b). When phosphorus(V) chloride, PCl_5, and ammonium chloride are heated together, the compound $P_3N_3Cl_6$ is formed, together with HC*l* gas.

$P_3N_3Cl_6$ has a cyclic structure, like the Kekulé structure of benzene.

i. Write an equation for the reaction of PCl_5 and ammonium chloride to form $P_3N_3Cl_6$.

[1]

ii. Calculate the percentage by mass of P in $P_3N_3Cl_6$.

Give your answer to **2** decimal places.

percentage by mass of P = ... % **[2]**

iii. Suggest **one** example of evidence that could show that $P_3N_3Cl_6$ has a Kekulé structure rather than a delocalised structure.

[1]

iv. In a molecule of $P_3N_3Cl_6$ all the N and Cl atoms are bonded to P atoms.
Suggest a possible structure for a molecule of $P_3N_3Cl_6$.

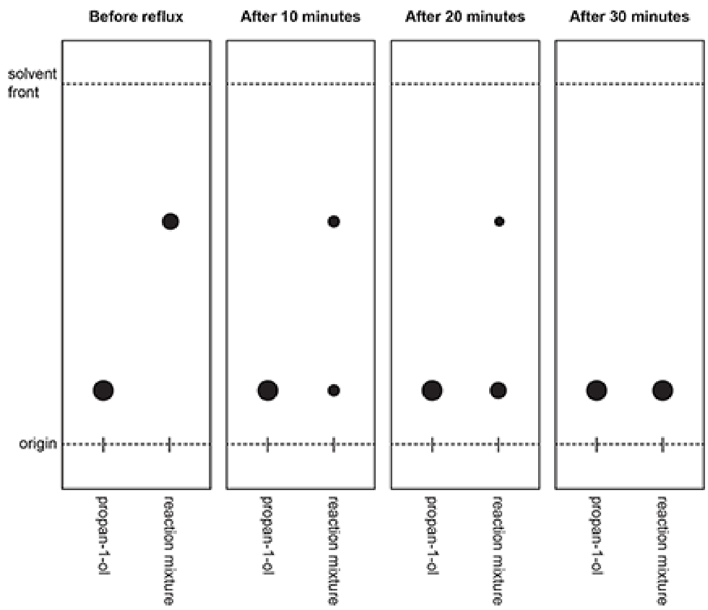
[2]

3. This question is about the analysis of organic compounds.

A student investigates the alkaline hydrolysis of 1-bromopropane as outlined below.

Step 1	The student adds 1-bromopropane to an excess of aqueous potassium hydroxide, KOH(aq), in a pear-shaped flask.
Step 2	A TLC chromatogram is run using propan-1-ol and the reaction mixture.
Step 3	The reaction mixture is refluxed. A TLC chromatogram of the reaction mixture is run every 10 minutes.

The TLC chromatograms are shown below



i. Determine the R_f value of propan−1−ol.

Show your working.

R_f = ... **[1]**

ii. Write an equation for the alkaline hydrolysis of 1−bromopropane.

Show structures of organic compounds.

[1]

iii. A student investigates the alkaline hydrolysis of 1−chloropropane using the same method as for 1−bromopropane.

Predict, with reasons, how the appearance of the reaction mixture in the chromatogram produced after 20 minutes would be different when 1−chloropropane is used instead of 1−bromopropane.

Suggest why propan−1−ol is run alongside the reaction mixture.

[3]

4. Compound **A** is a chloride of a Period 3 element.

A student carries out the 2 steps below to find the formula of compound **A**.

Step 1	The student adds 5.00×10^{-4} mol of compound **A** to water. A colourless solution is formed.
Step 2	The colourless solution reacts with exactly 60.0 cm^3 of 2.50×10^{-2} mol dm^{-3} $AgNO_3(aq)$ to form a white precipitate.

i. Write an ionic equation, with state symbols, for the reaction in **Step 2**.

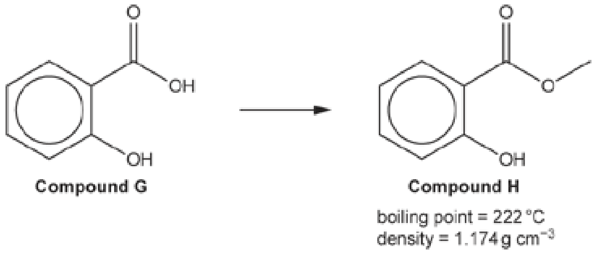
[1]

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

formula of **A** = ... **[3]**

5. Oil of wintergreen is a liquid used in medicine to relieve muscle pain.

Compound **H** is a component in oil of wintergreen and can be synthesised from compound **G**, as shown below. The boiling point and density of compound **H** are stated.



A student prepares a sample of compound **H** by the method below.

Step 1	Reflux 8.97 g of compound **G** for 30 minutes with an excess of methanol in the presence of a small amount of sulfuric acid as a catalyst.
Step 2	Add an excess of aqueous sodium carbonate, Na_2CO_3(aq). Two layers are obtained.
Step 3	Purify the impure compound **H** that forms from the resulting mixture.

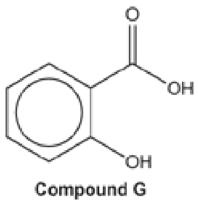
The student follows this method and obtains 5.32 g of pure compound **H**.

i. **In Step 2**, Na_2CO_3(aq) removes the sulfuric acid catalyst **and** any unreacted compound **G** from the mixture.

Write equations for this removal.

Removal of sulfuric acid

Removal of unreacted compound **G**



[3]

ii. Another student suggests that adding aqueous sodium hydroxide would be more effective in removing the sulfuric acid catalyst than Na_2CO_3(aq).

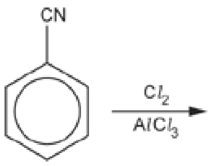
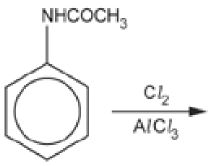
Comment on whether the student's suggestion is an improvement for the preparation of compound **H**.

[1]

6. The table shows directing effects for different groups in the electrophilic substitution of aromatic compounds.

Directing effect	2- and 4- directing	3-directing
Group	−OH	$-NO_2$
	$-NH_2$	$-COCH_3$
	$-NHCOCH_3$	−CN

i. Draw all organic products formed from monosubstitution reactions of the substituted benzene compounds shown below.

Reaction	Monosubstituted Product(s)
	
	

[3]

ii. The reactions of $C_6H_5NH_2$ are similar to the reactions of phenol.

Write an equation for the tri-substitution of $C_6H_5NH_2$ with chlorine.

[2]

iii. Explain why chlorine reacts much more readily with $C_6H_5NH_2$ than with benzene.

[3]

7. 1,6-Diaminohexane, $H_2N(CH_2)_6NH_2$, reacts with hexanedioyl dichloride, $ClOC(CH_2)_4COCl$ to form a polyamide and one other product.

What is the other product formed in this reaction?

A HCl
B H_2O
C CO
D NH_3

Your answer ☐ **[1]**

8. This question is about iron.

Iron can be extracted from iron ores containing the oxide Fe_2O_3.

i. What is the systematic name for Fe_2O_3?

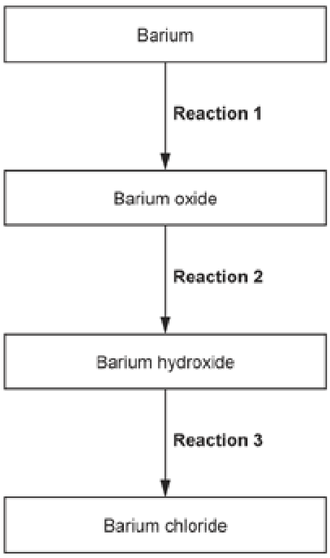
-- **[1]**

ii. Balance the equation for the reduction of Fe_2O_3 with carbon monoxide.

.... Fe_2O_3 + ... $CO \rightarrow$ .... Fe + ... CO_2

[1]

9. The flowchart shows some reactions of barium and its compounds.



- Write balanced equations for **Reaction 1** and **Reaction 2**.
- Identify the type of reaction in **Reaction 3**.

Reaction 1: equation

Reaction 2: equation

Reaction 3: type of reaction

[3]

10(a). Enthalpy changes of reaction can be determined by experiment.

A student carries out an experiment to determine the enthalpy change for the reaction between zinc and copper(II) nitrate solution.

$Zn(s) + Cu(NO_3)_2(aq) \rightarrow Zn(NO_3)_2(aq) + Cu(s)$ $\Delta_r H$ **Equation 3.1**

The student follows the method outlined below.

- Add 100 cm^3 of 0.500 mol dm^{-3} $Cu(NO_3)_2(aq)$ to a beaker.
- Measure the temperature of the solution.
- Add excess zinc to the beaker.
- Stir the mixture and record the maximum temperature.

The temperature of the solution changes from 19.5 °C to 38.1 °C.

Calculate $\Delta_r H$, in kJ mol^{-1}, for **equation 3.1.**

State any assumptions you have made in your calculation.

Suggest improvements for obtaining a more accurate value for $\Delta_r H$.

[6]

(b). The student modifies the experiment using 50 cm^3 instead of 100 cm^3 of 0.500 mol dm^{-3} copper(II) nitrate solution.

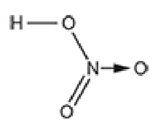
The value of $\Delta_r H$ for this modified experiment is the same as in **equation 3.1.**

Explain why.

[2]

11(a). This question is about nitric acid, hydrochloric acid and sulfuric acid.

Nitric acid has 2 single covalent bonds, 1 double covalent bond and 1 dative covalent bond as shown below.



Nitric acid

Predict the H–O–N and O–N–O bond angles in nitric acid.

Explain your reasoning.

[4]

(b). Dilute nitric acid reacts with aluminium oxide to form a solution of aluminium nitrate.

i. Write an equation for this reaction.

[2]

ii. The solution contains nitrate ions, NO_3^-.

Draw a 'dot-and-cross' diagram for the NO_3^- ion.

Use a different symbol for the extra electron.

[2]

12(a). Tutton's salts are 'double salts' with the formula $\mathbf{X}_2\mathbf{Y}(\mathbf{Z}O_4)_2 \cdot 6H_2O$.

A Tutton's salt contains two cations: $\mathbf{X}^+$ and $\mathbf{Y}^{2+}$.

- $\mathbf{X}^+$ can be an ion of the Group 1 elements K, Rb, Cs or Fr, or an ammonium ion.
- $\mathbf{Y}^{2+}$ can be a 2+ ion of magnesium or an ion of most of the transition elements in Period 4.
- **Z** can be S or Cr.

$(NH_4)_2Cu(SO_4)_2 \cdot 6H_2O$ is an example of a Tutton's salt.

Predict the formula of a Tutton's salt containing different ions from $(NH_4)_2Cu(SO_4)_2 \cdot 6H_2O$.

[1]

(b). A student prepares a sample of the Tutton's salt, $(NH_4)_2Cu(SO_4)_2 \cdot 6H_2O$ using the method shown below.

Step 1	Dissolve 0.025 mol of ammonium sulfate and 0.025 mol of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, in water and make up to 50 cm^3.
Step 2	Boil the resulting mixture for 2 minutes and allow to cool.
Step 3	Allow the solvent to evaporate slowly. Pale blue crystals of the Tutton's salt form.

i. What masses are needed of ammonium sulfate and $CuSO_4 \cdot 5H_2O$?

mass of ammonium sulfate .... g

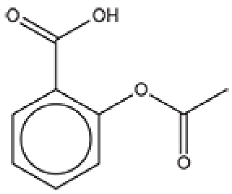
mass of $CuSO_4 \cdot 5H_2O$ .... g
[2]

ii. In **Step 3**, why does the student allow the solvent to evaporate and **not** boil off all the solvent in **Step 2**?

[1]

13. Aspirin tablets are used for pain relief.

The structure of aspirin is shown below.



Aspirin

Aspirin reacts with hot NaOH(aq), under reflux.

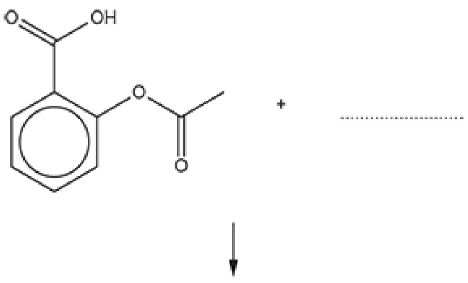
i. Draw a labelled diagram of suitable apparatus for reflux.

[2]

ii. In this reaction, 1 mol of aspirin reacts with 3 mol of hot NaOH(aq).

Complete the equation for the reaction of aspirin with an excess of hot NaOH(aq).

Show structures for organic compounds.



[3]

14(a). This question is about acids and bases.

Table 20.1 shows the ionic product, K_w, of water at 25 °C and 40 °C.

Table 20.1

Temperature / °C	**K_w / mol² dm⁻⁶**
25	1.00×10^{-14}
40	2.92×10^{-14}

i. Calculate the pH of water at 40 °C.

Give your answer to **2** decimal places.

pH = ... **[2]**

ii. **Table 20.1** shows different K_w values at 25 °C and at 40 °C. A student suggests that water is neutral at these temperatures.

Explain why this student is correct.

[1]

(b). A student reacts strontium metal with water to make a 250.0 cm³ solution of aqueous strontium hydroxide, $Sr(OH)_2$. The solution contains 0.145 g of strontium hydroxide.

- Write an equation for the reaction of strontium with water.
- Calculate the pH of this 250.0 cm³ solution of strontium hydroxide at 40 °C. You should refer back to **Table 20.1** at the start of **(a)**.

Give your answer to **2** decimal places.

Equation

Calculation

pH = ... **[5]**

(c). A student reacts 1.00 g of strontium carbonate, $SrCO_3$, with an excess of dilute nitric acid, HNO_3. A gas is produced.

i. Construct the equation for this reaction.

[1]

ii. The student then reacts 1.00 g of calcium carbonate, $CaCO_3$, with an excess of dilute nitric acid, HNO_3.

Explain why the student's two reactions produce different volumes of gas.

[2]

15. An acidified solution containing $Cr_2O_7^{2-}$ ions reacts with vanadium(III) ions in a redox reaction to form a solution containing Cr^{3+} ions and VO_2^{+} ions.

Construct the overall equation for this reaction.

[2]

16. The equations show the electrode potentials of the half-cells used in a lithium-ion cell.

	$E^{\ominus}$ / V
$Li^+ + e^- \rightleftharpoons Li$	–3.04
$Li^+ + CoO_2 + e^- \rightleftharpoons LiCoO_2$	+1.16

Which statement is correct in a lithium-ion cell?

A The cell potential is 2.88 V.
B The reaction at the positive electrode is: $LiCoO_2$ $Li^+ + CoO_2 + e^-$
C The overall cell reaction is: $Li + CoO_2 \rightarrow LiCoO_2$
D The oxidation number of Co changes from +2 to +1.

Your answer ☐ **[1]**

17. This question is about the oxidation of two alcohols that are structural isomers of C_3H_8O.

Compare the oxidation of these two structural isomers using different reaction conditions.

For each reaction include:

- the reaction conditions
- the functional group of any organic product
- a balanced equation.

In your equations, use [O] to represent the oxidising agent and show any organic compounds as structures.

[5]

18. This question is about reactions involving acids.

Write equations for the reactions below. State symbols are **not** required.

i. The reaction of copper(II) oxide with dilute hydrochloric acid.

-- **[1]**

ii. The reaction of ammonium carbonate with dilute nitric acid.

-- **[2]**

19. This question is about enthalpy changes.

In a petrol engine, alkanes undergo combustion.

i. Heptane is one of the alkanes in petrol.

Write the equation for the complete combustion of heptane.

State symbols are **not** required.

-- **[2]**

ii. In a petrol engine, polluting gases such as CO and NO are formed. These are mostly removed before being emitted from the exhaust.

The equation for the removal of CO and NO is shown below.

$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$ ΔH = –746 kJ mol^{-1}

Complete the enthalpy profile diagram in **Fig. 23.1** for this reaction.

On your diagram:

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

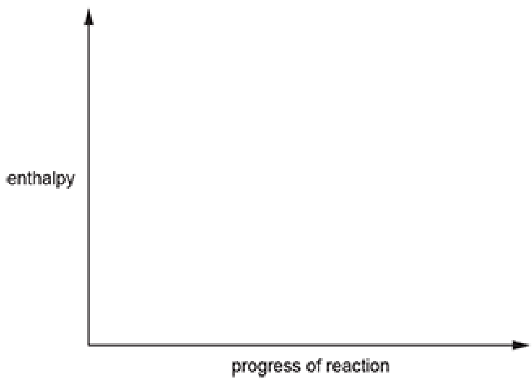


Fig. 23.1

[2]

iii. CO and NO are removed by use of a catalyst.

Explain the role of the catalyst.

Refer to your enthalpy profile diagram in **Fig. 23.1** in your answer.

[2]

20. Successive ionisation energies, in kJ mol^{-1}, of an element in Period 3 of the periodic table are shown below.

1st	2nd	3rd	4th	5th	6th	7th	8th	9th
578	1817	2745	11578	14831	18378	23296	27460	31862

What is the formula of the oxide of the Period 3 element?

A Na_2O
B MgO
C Al_2O_3
D SiO_2

Your answer **[1]**

21. 2-methylpentane reacts with bromine by radical substitution.

2-methylpentane

A mixture of organic products is formed, including 3-bromo-2-methylpentane, and compounds **A** and **B**.

i. Complete the table below to show the mechanism for the formation of 3-bromo-2-methylpentane and **three** possible equations for termination.

In your equations, use **structural or skeletal formulae** and 'dots' (•) for the position of radicals.

Initiation	Equation: .... Conditions: ....

Propagation	⟶ ⟶
Termination	⟶ ⟶ ⟶

[6]

ii. Organic compound **A** is formed by the substitution of **all** 14 H atoms in 2-methylpentane by Br atoms.

Write the equation, using **molecular formulae**, for the formation of compound **A** from 2-methylpentane.

[2]

iii. Organic compound **B** is formed by the substitution of **some** of the 14 H atoms in 2-methylpentane by Br atoms.

0.8649 g of compound **B** is heated until it is vaporised.

Under the conditions used:

- compound **B** has a volume of 72.0 cm^3
- the molar gas volume is 40.0 dm^3 mol^{-1}.

Determine a possible molecular formula of compound **B**.

molecular formula = ... **[3]**

22. This question is about alcohols.

An **unsaturated** alcohol has 6 carbon atoms and contains **one** C=C bond.

Construct an equation for the complete combustion of this alcohol.

[2]

23. For complete combustion, 0.100 mol of an alkane requires 22.8 dm^3 of O_2, measured at RTP.

Which alkane has undergone complete combustion?

A pentane
B hexane
C heptane
D octane

Your answer ☐ **[1]**

24(a). This question is about some elements in Period 3 and compounds they form.

A student adds a small piece of calcium to a beaker containing an excess of water.

i. Construct the equation for the reaction and predict **one** observation that the student would make.

Equation

Observation

[2]

ii. Suggest **one** difference that the student would observe in the reaction of barium with water compared to the reaction of calcium with water.

[1]

(b). A student has a 5.00 g mixture of sodium chloride, $NaCl(s)$, and barium nitrate, $Ba(NO_3)_2(s)$.

The student also has a solution of sodium sulfate, $Na_2SO_4(aq)$.

The student uses the method below to determine the percentage by mass of NaC*l*(s) in the mixture.

Step 1 Dissolve the 5.00g mixture in distilled water.
Step 2 Add an excess of Na_2SO_4(aq) to the solution. A precipitate of barium sulfate forms.
Step 3 Filter off the precipitate, wash with water, and dry.
Step 4 Weigh the dried precipitate.

The molar mass of barium sulfate is 233.4 g mol^{-1}.

i. Write an equation for the formation of barium sulfate in **step 2**.

Include state symbols.

[2]

ii. The student obtains 3.28 g of precipitate.

Calculate the percentage by mass of NaC*l*(s) in the 5.00 g mixture.

Give your answer to **3** significant figures.

percentage by mass of NaC*l* (s) = ... % **[4]**

iii. The student changes the method in **2(b)**.

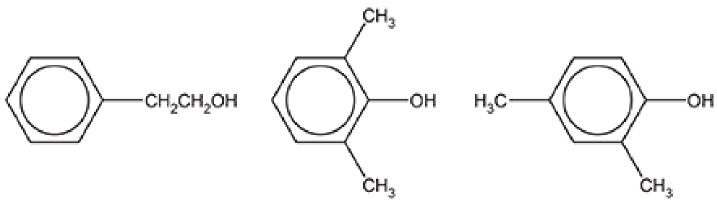
In **step 2**, the student adds an excess of silver nitrate solution, $AgNO_3$(aq), instead of Na_2SO_4(aq).

Explain whether this change would allow the student to determine the percentage by mass of NaC*l*(s) in the mixture.

[2]

25(a). This question is about the chemistry of aromatic compounds.

Compounds **J**, **K** and **L**, shown below, are structural isomers.



Compound J Compound K Compound L

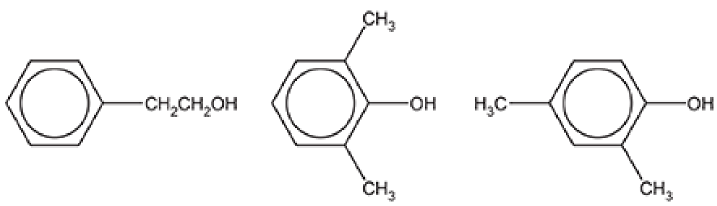
Compound **J**, $C_6H_5CH_2CH_2OH$, is reacted with acidified potassium dichromate(VI) under reflux to form organic product **M**.

Write an equation for this reaction.

Use [O] to represent the oxidising agent and show the structure of **M**.

[2]

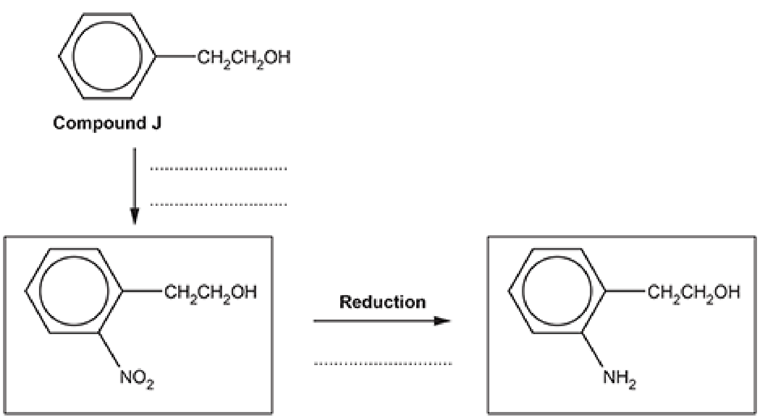
(b). Compounds **J**, **K** and **L**, shown below, are structural isomers.



Compound J Compound K Compound L

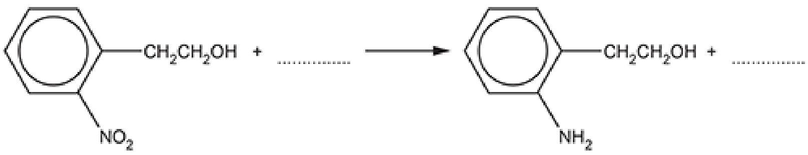
A two-stage synthesis of an amine from compound **J** is shown below.

i. Add the reagents for each stage of this synthesis.



[2]

ii. Fill in the equation for the reduction stage of this synthesis.



[1]

(c). 1-phenylethanol is a naturally occurring compound found in many vegetables and flowers.

1-phenylethanol can be synthesised from 2-phenylethanol in two stages.

Suggest reagents, conditions and equations for each stage in the synthesis.

Show structures for organic compounds.

Stage 1

reagents and conditions ....

equation:

Stage 2

reagents and conditions ....

equation:

[4]

(d). Acid anhydrides react in a similar way to acyl chlorides with phenols.

Benzoic anhydride is the acid anhydride of benzoic acid, C_6H_5COOH.

Benzoic anhydride reacts with butan-2-ol to form an ester.

Suggest an equation for this reaction. Show structures for organic compounds. Use C_6H_5 for any phenyl groups.

[2]

26. This question is about compounds that contain the carboxylic acid functional group.

Carboxylic acids react with alkalis, metals and carbonates to form salts.

Write full equations for the following **three** reactions. Show structures for organic compounds.

- the reaction of propanoic acid with aqueous potassium hydroxide:
- the reaction of aqueous methanoic acid with magnesium:
- the reaction of the α−amino acid, aspartic acid ($R=CH_2COOH$), with an excess of aqueous sodium carbonate, Na_2CO_3:

[4]

27(a). This question is about halogens and practical tests

Chlorine gas reacts with dilute sodium hydroxide, NaOH(aq). This is a disproportionation reaction. One of the products has the formula $NaClO$.

i. What is meant by the term **disproportionation**?

[1]

ii. Construct the equation for the reaction of chlorine with dilute sodium hydroxide.

Use your equation to explain that disproportionation has taken place.

Equation ....

Explanation ....

[3]

(b). A student is supplied with aqueous solutions of ionic compounds **B** and **C**.

Compound **B** is a chloride, bromide or iodide of a Group 1 element.

Compound **C** is a chloride, bromide or iodide of a Group 2 element.

The molar masses of **B** and **C** are both in the range 100–115 g mol^{-1}.

Use this information and test-tube tests to show how the student could identify the halide present in **B** and **C** and the formulae of **B** and **C**.

Explain your reasoning.

In your answer, include observations, colours and equations.

[5]

28. The first four ionisation energies of a Period 3 element **X** are shown in the table.

Ionisation energy/kJ mol^{-1}			
1st	**2nd**	**3rd**	**4th**
738	1451	7733	10 541

Element **X** is reacted with chlorine.

What is the formula of the chloride formed?

A **X**C*l*
B **X**Cl_2
C **X**Cl_3
D **X**Cl_4

Your answer ☐ **[1]**

29. What is the number of **ions** in 4.00 mol of magnesium chloride, MgCl_2?

A 1.81×10^{24}
B 2.41×10^{24}
C 4.82×10^{24}
D 7.22×10^{24}

Your answer ☐ **[1]**

30(a). This question is about the reactions of Group 2 metals and their compounds.

A sample of barium oxide is added to distilled water at 25 °C.
A colourless solution forms containing barium hydroxide, $Ba(OH)_2$.

The solution is made up to 250.0 cm^3 with distilled water.
The pH of this solution is 13.12.

i. Determine the mass of barium oxide that was used.

Give your answer to **3** significant figures.

mass of barium oxide = ... g **[5]**

ii. 10 cm^3 of dilute sulfuric acid is added to 10 cm^3 of the colourless solution of $Ba(OH)_2$. Write an ionic equation, including state symbols, for the reaction.

[1]

(b). Limestone and huntite are two calcium minerals.

i. A typical sample of limestone contains 95.0% by mass of calcium carbonate, $CaCO_3$. Fertiliser **Z**, $Ca_5NH_4(NO_3)_{11} \cdot 10H_2O$ (M_r = 1080.5 g mol^{-1}) can be made from limestone. Calculate the mass, in g, of limestone needed to make 1.50 kg of fertiliser **Z**.

Give your answer to **3** significant figures.

mass of limestone = ... g **[3]**

ii. Huntite is a carbonate mineral with the chemical formula $Mg_3Ca(CO_3)_4$.

Huntite reacts with dilute hydrochloric acid to produce bubbles of a gas and a colourless solution.

Construct the equation for the reaction. Include state symbols.

[2]

31(a). This question is about reactions of transition metal compounds.

Aqueous sodium hydroxide is added to an aqueous solution of iron(II) sulfate.

A pale green precipitate forms which turns brown when left to stand in air.

i. Write an ionic equation for the formation of the pale green precipitate.

[1]

ii. Use the information below to explain why the pale green precipitate turns brown when left to stand in air and construct an equation for the reaction which occurs.

Redox System	Equation	$E^{\ominus}/V$
1	$Fe(OH)_3(s) + e^- \rightleftharpoons Fe(OH)_2(s) + OH^-(aq)$	−0.56V
2	$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40V

[4]

(b). * This question is about copper and copper compounds.

Experiment 1

Hydrochloric acid, HC*l*(aq), is added to an aqueous solution containing $[Cu(H_2O)_6]^{2+}$ complex ions.

A yellow-green solution forms containing complex ion **B**.

Experiment 2

A piece of copper metal is heated with concentrated sulfuric acid.

A reaction takes place forming a pale blue solution **C** and 45 cm^3 of a gas **D**, measured at RTP. The mass of gas **D** is 0.12 g.

Experiment 3

An excess of copper(II) oxide is heated with dilute nitric acid. The resulting mixture is filtered. The filtrate is a blue solution **E**.
Aqueous potassium iodide, KI(aq), is added to the blue solution **E**.
A white precipitate F and a brown solution **G** form.

Determine the formulae of **B–G**.
Construct equations for the reactions taking place, include any changes in oxidation number, and show your working where appropriate.

[6]

32. 20 cm^3 of nitrogen gas reacts with 10 cm^3 of oxygen gas to form 20 cm^3 of a gaseous product. Which equation is the most likely for the reaction?

A $N_2(g) + O_2(g) \rightarrow 2NO(g)$
B $N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$
C $2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$
D $2N_2(g) + 2O_2(g) \rightarrow 4NO(g)$

Your answer ☐ [1]

33. Prussian blue, $C_{18}Fe_7N_{18}$, is a deep blue pigment containing Fe^{2+}, Fe^{3+} and CN^- ions.

What are the numbers of Fe^{2+} and Fe^{3+} ions in one formula unit of $C_{18}Fe_7N_{18}$?

A 2 Fe^{2+} and 5 Fe^{3+}
B 3 Fe^{2+} and 4 Fe^{3+}
C 4 Fe^{2+} and 3 Fe^{3+}

D 5 Fe^{2+} and 2 Fe^{3+}

Your answer ☐ **[1]**

34(a). This question is about some Group 2 elements and their compounds.

A student adds barium oxide, BaO, to water.

A reaction takes place forming a colourless solution.

i. Predict the approximate pH of the colourless solution.

pH = ... **[1]**

ii. A student adds a few drops of dilute sulfuric acid to the colourless solution.

Describe what the student would observe, and give the formula of the barium compound produced.

Observation

Formula of barium compound

[2]

(b). Strontium and calcium both react with water.

i. Write an equation for the reaction of strontium with water.

[1]

ii. Using oxidation numbers, explain why the reaction of strontium with water is a redox reaction.

[2]

iii. Explain why calcium reacts more slowly with water than strontium does.

[3]

35. Internal combustion engines have historically used fuels obtained from crude oil as a source of power.

The environmental effects of fossil fuel use can be reduced by blending petrol with biofuels such as ethanol.

A fuel is being developed using a 1:1 molar ratio of octane and ethanol.

i. Write the equation for the complete combustion of this fuel.

-- **[1]**

ii. Calculate the energy released, in kJ, by the complete combustion of 8.00 kg of this fuel.
$\Delta_c H(C_8H_{18}) = -5470\ kJ\ mol^{-1}$; $\Delta_c H(C_2H_5OH) = -1367\ kJ\ mol^{-1}$.

energy released = ... kJ **[3]**

36. Glycine, H_2NCH_2COOH, is an α-amino acid.

i. Glycine reacts with NaOH to form the salt H_2NCH_2COONa.

Glycine reacts with HC*l* to form the salt $HOOCCH_2NH_3Cl$.

The salts have different H-N-H bond angles.

State the different H-N-H bond angles and explain why they are different.

H_2NCH_2COONa H-N-H bond angle = ... °

$HOOCCH_2NH_3Cl$ H-N-H bond angle = ... °

explanation

-- **[3]**

ii. Glycine reacts with aqueous copper(II) ethanoate to form copper(II) glycinate, $Cu(H_2NCH_2COO)_2$, and ethanoic acid. Copper(II) glycinate is a complex which exists as two square planar isomers.

Write an equation for this reaction and draw the structures of the two square planar isomers of the complex $Cu(H_2NCH_2COO)_2$.

equation

structures

[3]

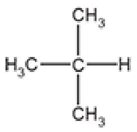
37. A student bubbles hydrogen sulfide gas, $H_2S(g)$, through an acidified solution containing manganate(VII) ions, $MnO_4^-(aq)$.

A redox reaction takes place, forming aqueous manganese(II) ions, a yellow precipitate and one other product.

Construct the equation for this reaction. State symbols are not required.

[2]

38(a). Alkane **A**, shown below, reacts with bromine in a radical substitution reaction.



Alkane A

In this reaction with bromine, monosubstitution of alkane **A** forms a mixture of organic products.

Show the structures of **two** monosubstituted organic products that are formed.

[2]

(b). With excess bromine, further substitution takes place.

Write an equation for the reaction of alkane **A** with excess bromine to produce 1,3-dibromo-2-methylpropane.

Use structures for the organic compounds.

[2]

39(a). A student carries out an experiment to determine the percentage by mass of copper in an ore containing copper in its +2 oxidation state.

The student is provided with a sample of the copper ore, 1 mol dm^{-3} potassium iodide, KI(aq), and 0.0200 mol

dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.

The student's method is outlined below.

Step 1	Add an excess of warm nitric acid to 2.50 g of the ore. The copper(II) compounds in the ore react, forming aqueous copper(II) nitrate.
Step 2	Filter the mixture to remove the unreacted rock. Neutralise the filtrate.
Step 3	Add an excess of aqueous potassium iodide, KI(aq). A precipitate of copper(I) iodide and a solution of iodine, I_2(aq), forms.
Step 4	Titrate the mixture from **Step 3** using 0.0200 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$ in the burette. $I_2(aq) + 2S_2O_3{}^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6{}^{2-}(aq)$ 26.55 cm^3 of 0.0200 mol dm^{-3} $Na_2S_2O_3$ are required to reach the end point.

In **Step 1**, the student observed that bubbles of gas were produced.

Suggest the formula of the copper(II) compound which reacted with HNO_3 to form the gas, and write a full equation for the reaction.

Formula:

Equation: .... **[2]**

(b). Write an **ionic** equation, including state symbols, for the reaction in **Step 3**.

.... **[1]**

(c). Suggest a suitable indicator for this titration and state the colour change at the end point in **Step 4**.

Indicator:

Colour from .... to .... **[1]**

(d). Determine the percentage, by mass, of copper in the copper ore.
Give your answer to an **appropriate** number of significant figures.

percentage = ... % **[4]**

(e). Explain whether the calculated percentage by mass of copper would be higher, lower or the same if the following changes were made to the method.

i. The potassium iodide was not in excess, in **Step 3**.

[1]

ii. The burette readings were read from the top of the meniscus, in **Step 4**.

[1]

(f). The student then modifies the method in order to obtain a more accurate value for the percentage by mass of copper in the ore. The student decides to use 25.00 g of the copper ore in **Step 1**.

What further modifications should the student make to produce a more accurate value for the percentage by mass of copper in the ore?

[2]

40(a). This question is about nitrogen and its compounds.

Hydrazoic acid, HN_3, is a weak acid ($K_a = 2.51 \times 10^{-5}$ mol dm^{-3}).

i. Calculate the pH of 0.125 mol dm^{-3} hydrazoic acid.
Give your answer to **2** decimal places.

pH = ...[2]

ii. When added to water, hydrazoic acid forms an equilibrium mixture containing conjugate acid–base pairs.
Complete the equation for this equilibrium and label the conjugate acid–base pairs as: **A1**, **B1** and **A2**, **B2**.

Equation	HN_3	+	....	$\rightleftharpoons$	....	+	....
Acid-base pairs	....		....		....		....

[2]

iii. In the Schmidt reaction, hydrazoic acid, HN_3, reacts with carboxylic acids to form primary amines.

For example, HN_3 reacts with RCOOH to form RNH_2 and two gases that are found in the atmosphere.

Write the equation for the reaction of HN_3 with 2-methylbutanoic acid.

Show structures for organic compounds.

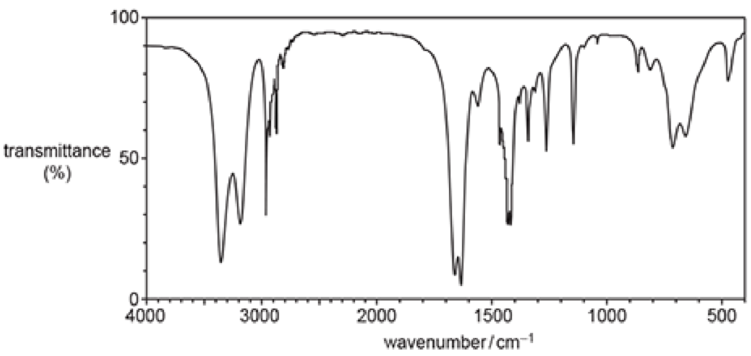
[3]

(b). This question is about two reactions of ammonia.

Reaction 1
Excess ammonia is reacted with 4.77 g of copper(II) oxide. The reaction produces 3.81 g of solid **E**, liquid **F** and 0.560 g of gas **G**, which has a volume of 480 cm^3 at RTP.

Reaction 2
Ammonia reacts with compound **H** to form compound **I**, C_2H_5NO, and chloride salt **J**.

The IR spectrum of **I** is shown below.



Identify **E**, **F**, **G**, **H**, **I** and **J**, and write equations for the **two** reactions.

Show your reasoning.

[6]

41(a). Compound **A** has the following percentage composition by mass:

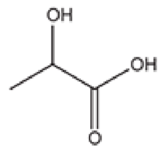
Ca, 81.10%; N, 18.90%.

A student reacts compound **A** with water to form alkaline gas **B** and alkali **C**.

Identify **A**, **B** and **C** and write the equation for the reaction of compound **A** with water.

[4]

(b). The structure of lactic acid is shown below.



lactic acid

Complete and balance the equations for two reactions of lactic acid.

Reaction with sodium carbonate

$CH_3CH(OH)COOH$ + ... → ....

Reaction with aluminium

$CH_3CH(OH)COOH$ + ... → ....

[4]

42(a). Europium (A_r = 152.0) reacts with dilute aqueous acid in a redox reaction, forming a solution and hydrogen gas.

A student proposed three possible ionic equations for this reaction, forming europium ions with different charges:

Equation 1 $2Eu(s) + 2H^+(aq) \rightarrow 2Eu^+(aq) + H_2(g)$

Equation 2 $Eu(s) + 2H^+(aq) \rightarrow Eu^{2+}(aq) + H_2(g)$

Equation 3 $2Eu(s) + 6H^+(aq) \rightarrow 2Eu^{3+}(aq) + 3H_2(g)$

The student plans to carry out an investigation to determine which equation is correct.

Hydrochloric acid is used as the source of $H^+(aq)$ ions.

The student's method is outlined below.

Step 1	Using a 3 decimal place balance, weigh a suitable container for the reaction. Add about 1 g of europium to the container and reweigh.
Step 2	Set up apparatus for gas collection. Add an excess of dilute hydrochloric acid to the europium.
Step 3	Measure the volume of gas produced.

Results

Mass of container	= 32.795 g
Mass of container + europium	= 33.783 g
Volume of gas collected	= 152 cm^3

Draw a labelled diagram of suitable apparatus for this investigation.

[2]

(b). Analyse the student's results to conclude which of **Equation 1** or **2** or **3**, is supported by the experimental results.

Assume that the conditions in the laboratory are 'room temperature and pressure' (RTP).

correct equation (**1**, **2**, or **3**) = ...**[3]**

(c). The student repeats the experiment but adds concentrated hydrochloric acid instead of dilute hydrochloric acid. The apparatus gets hot during the reaction.

Predict how the hot apparatus would change the student's results and the conclusion in **(b)**.

Explain your answer.

[2]

(d). The student modifies their method as outlined below:

- 1.52 g (0.01 mol) of europium is reacted with an excess of dilute hydrochloric acid.
- An excess of aqueous sodium hydroxide is added to the reaction mixture.
- A precipitate forms which is collected, dried and weighed.

Explain how the mass of precipitate formed would allow the student to conclude which of **Equation 1** or **2** or **3** is correct.

[2]

43. The unbalanced equation for the reaction of silver with concentrated nitric acid is shown below.

….. $Ag(s)$ + ….. $NO_3^-(aq)$ + ….. $H^+(aq)$ → ….. $Ag^+(aq)$ + ….. $NO(g)$ + ..… $H_2O(l)$

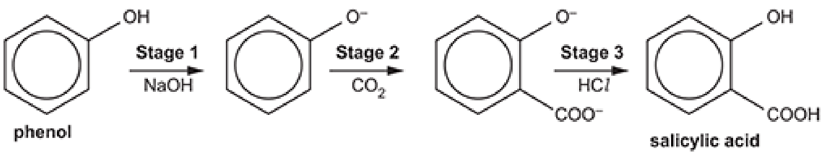
Which numbers for Ag and H_2O will balance the equation?

	Ag(s)	$H_2O(l)$
A	1	2
B	2	3
C	3	1
D	3	2

Your answer ☐ **[1]**

44. This question is about reactions of phenol.

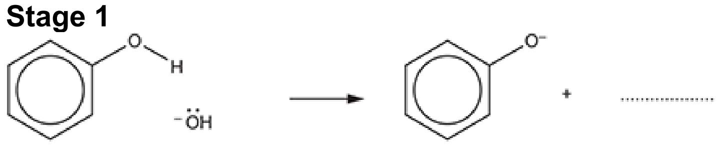
Salicylic acid can be prepared from phenol as shown below.



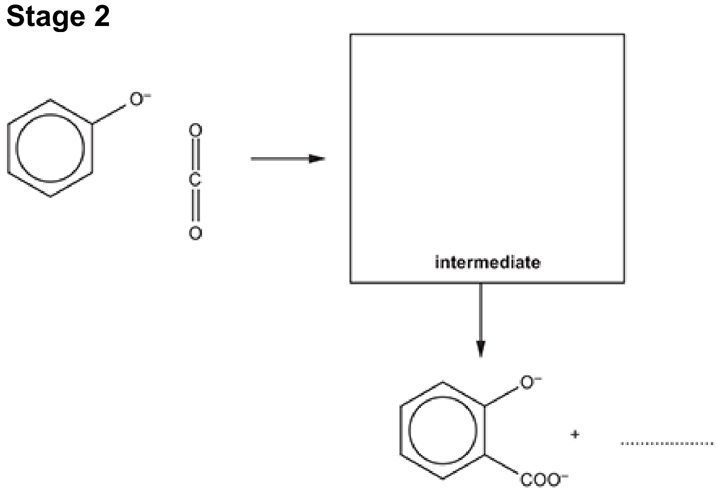
i. Complete the mechanism below for **Stage 1** and **Stage 2**.

Show curly arrows, the structure of the intermediate and the missing formulae on the dotted lines.

Stage 1



Stage 2



[6]

ii. What are the roles of ^-OH and CO_2 in the mechanism?

^{-}OH

CO_2

[2]

iii. Two molecules of salicylic acid can react together in the presence of an acid catalyst to form compound **B**.

Compound **B** has three rings and a molecular formula of $C_{14}H_8O_4$.

Write the equation for this reaction showing the structures of organic compounds.

[3]

45(a). Compounds **A** and **B** are structural isomers of $(CH_3)_3COH$.

i. Compound **A** is a secondary alcohol.

What is the systematic name of compound **A**?

[1]

ii. Compound **B** is a branched primary alcohol.

Compound **B** is refluxed with acidified potassium dichromate(VI) as an oxidising agent.

Write the equation for the reaction that takes place.

Use structures for organic compounds and [O] for the oxidising agent.

[3]

(b). 2-Chloro-2-methylpropane, $(CH_3)_3CCl$, is an organic liquid with a boiling point of 50 °C.

A student prepares $(CH_3)_3CCl$ by reacting 2-methylpropan-2-ol, $(CH_3)_3COH$, with concentrated hydrochloric acid.

Write a balanced equation for this reaction.

Use skeletal formulae for organic compounds.

[2]

46(a). This question is about halogens.

A mixture of potassium perchlorate, $KClO_4$, and aluminium is used in fireworks.

When the firework ignites, $KClO_4$ reacts with aluminium to form potassium chloride, KCl , and aluminium oxide, Al_2O_3.

Write the balanced equation for this reaction.

State symbols are not required.

[1]

(b). A student investigates the trend in reactivity of the halogens Cl_2, Br_2 and I_2.

The student is supplied with:

- solutions of Cl_2, Br_2 and I_2 in cyclohexane (an organic solvent)
- aqueous solutions of the halides: $NaCl$, NaBr and NaI.

The colours of the halogen solutions in cyclohexane are shown below.

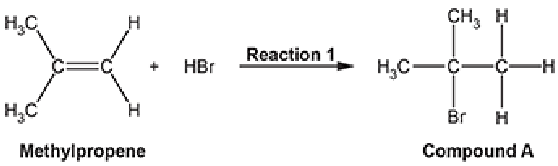
Halogen	Cl_2	Br_2	I_2
Colour in cyclohexane	Pale green	Orange	Violet

Plan an experiment on a test tube scale that would show the trend in the reactivity of the halogens Cl_2, Br_2 and I_2.

Include **all** the expected observations and an ionic equation for **one** of the reactions.

[5]

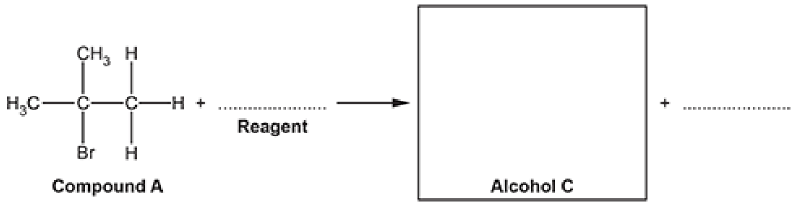
47. A student reacts methylpropene with hydrogen bromide, HBr, as shown in **Reaction 1**.



Compound A can be refluxed with a reagent to make alcohol C.

i. Choose a reagent for this reaction and complete the equation for this reaction.

Your equation should show the structure of alcohol **C**.

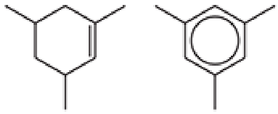


[2]

ii. Draw a labelled diagram to show how you would set up apparatus for reflux.

[2]

48. Compounds **B** and **C**, shown below, are unsaturated hydrocarbons containing nine carbon atoms.



B C

Compound **C** can be prepared by 'trimerisation' of propanone using concentrated sulfuric acid as a catalyst.

Suggest an equation for this reaction, using **molecular** formulae.

[3]

49(a). Alcohols can be used to prepare organic compounds with different functional groups.

$HO(CH_2)_4OH$ can be oxidised to form $HOOC(CH_2)_2COOH$.

i. State the reagents and conditions and write an equation for this oxidation.

In the equation, use [O] for the oxidising agent.

Reagents and conditions:

Equation:

[3]

ii. $HOOC(CH_2)_2COOH$ is soluble in water.

Explain, using a labelled diagram, why $HOOC(CH_2)_2COOH$ is soluble in water.

[2]

(b). HOOC$(CH_2)_2$COOH and HO$(CH_2)_4$OH react together to form polymer **E**.

i. Draw **one** repeat unit of polymer **E**.

The functional groups should be clearly displayed.

[2]

ii. Governments are encouraging the development of biodegradable polymers to reduce dependency on persistent plastic waste derived from fossil fuels.

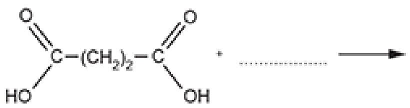
Polymer **E** is a biodegradable polymer.
Suggest why polymer **E** is able to biodegrade.

[1]

iii. A large yield of polymer **E** can be obtained by reacting a diacyl dichloride with HO$(CH_2)_4$OH.

The diacyl dichloride is prepared from HOOC$(CH_2)_2$COOH.

Complete the equation for the formation of a diacyl dichloride from HOOC$(CH_2)_2$COOH.



[3]

50. This question is about halogens.

A student adds a solution of bromine in an organic solvent to two test tubes.

The student adds aqueous sodium chloride to one test tube, and aqueous sodium iodide to the other test tube.

The student shakes the mixtures, allows them to settle, and records the colour of the organic layer in each mixture.

Sodium halide	**Colour of organic layer**
Sodium chloride	orange
Sodium iodide	violet

Explain how the student's results provide evidence for the trend in reactivity of the halogens down group 17(7) and write an ionic equation for any reaction that takes place.

Use your chemical knowledge to explain the trend in reactivity.

[5]

51. * **B** and **C** are compounds of two different transition elements.

A student carries out test tube reactions on aqueous solutions of **B** and **C**.
The observations of the student's tests are shown below.

	Test	**B(aq)**	**C(aq)**
1	NH_3(aq) added dropwise excess NH_3(aq) added	green precipitate **D** no further change	grey-green precipitate **E** purple solution **F**
2	HNO_3(aq) followed by $Ba(NO_3)_2$(aq)	no change white precipitate **G**	no change no change
3	HNO_3(aq) followed by $AgNO_3$(aq)	no change no change	no change white precipitate **H**

Analyse the results to identify **B** to **H**, and construct ionic equations for the formation of products **D** to **H**.

[6]

52. Which statement(s) for Group 2 elements is/are correct?

1 The 2nd ionisation energy of magnesium is greater than the 2nd ionisation energy of calcium.
2 A strontium ion, Sr^{2+}, contains a total of 6 electrons in s orbitals.
3 The equation for the reaction of barium with water is:
$2Ba + 2H_2O \rightarrow 2BaOH + H_2$.

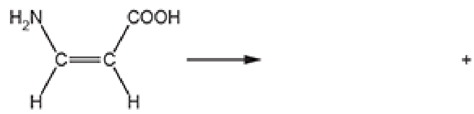
A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer ☐ **[1]**

53. This question is about organic chemistry.

The amino acid Z−$H_2NCH=CHCOOH$ can react to form a cyclic compound with the molecular formula C_3H_3NO and one other product.

Complete the equation for this reaction.



[2]

54. A student is provided with a sample of a metal **M**.

The student analyses metal **M** using a 'back-titration' technique:

- The metal is reacted with excess acid.
- The resulting solution is titrated to determine the amount of acid remaining after the reaction.

Stage 1
The student adds 100 cm^3 of 2.10 mol dm^{-3} HC*l* (aq) to 6.90 g of **M**.
An excess of HC*l* (aq) has been used to ensure that all of metal **M** reacts.

A redox reaction occurs, forming a solution containing **M** in the +2 oxidation state.

Stage 2
The resulting solution from **Stage 1** is made up to 250.0 cm^3 with distilled water.

Stage 3
A 25.00 cm^3 sample of the diluted solution from **Stage 2** is titrated with 0.320 mol dm^{-3} NaOH(aq).

The NaOH(aq) reacts with excess HC*l* (aq) that remains in **Stage 1**:

NaOH(aq) + HC*l* (aq) → NaC*l* (aq) + H_2O(l)

The student repeats the titration to obtain concordant titres.

Titration results (The trial titre has been omitted.)
The burette readings have been recorded to the nearest 0.05 cm^3

	1	**2**	**3**
Final reading / cm^3	27.80	37.55	32.20
Initial reading / cm^3	0.50	10.00	5.00

i. In **Stage 1**, a redox reaction takes place between **M** and HC*l* (aq), forming hydrogen and a solution containing **M** in the +2 oxidation state.

Write an overall equation, with state symbols, for this reaction. Write half-equations for the oxidation and reduction processes.

Overall equation

Oxidation half-equation

Reduction half-equation

[3]

ii. In **Stage 1**, suggest **two** observations that would confirm that all of metal **M** has reacted.

1

2

[2]

iii. In **Stage 3**, write the ionic equation for the reaction taking place in the titration.

[1]

iv. Metal **M** can be identified following the steps below.

1. The amount, in mol, of excess HC*l* (aq) that remains after the reaction of **M** with HC*l* (aq).
2. The amount, in mol, of HC*l* (aq) that reacted with **M**.
3. The identity of metal **M**.

Analyse the results to identify metal **M**.

Metal **M** = ... **[6]**

55. This question is about some elements in Period 4 of the periodic table.

The Period 4 element selenium is in the same group of the periodic table as oxygen.

Selenium and oxygen both form compounds with hydrogen with the formulae H_2Se and H_2O respectively.

i. H_2Se can be prepared by reacting aluminium selenide, Al_2Se_3, with water.
Aluminium hydroxide and hydrogen selenide are formed.

Write the equation for this reaction.

[1]

ii. The boiling points of H_2O and H_2Se are shown below.

Compound	**Boiling point / °C**
H_2O	100
H_2Se	–41

Explain why H_2O has a higher boiling point than H_2Se.

[3]

56. This question is about compounds of bromine.

Bromine reacts with phosphorus, P_4, to form phosphorus tribromide, PBr_3.

i. Complete the electron configuration of a bromine atom.

$1s^2$ [1]

ii. Write the equation for the reaction of phosphorus with bromine.

[1]

57. This question is about barium hydroxide.

A student plans to prepare a solution of $Ba(OH)_2$ from barium by two different reaction routes.

Outline **2** reaction routes for preparing a solution of $Ba(OH)_2$ from barium in the laboratory.

Include relevant equations.

[4]

58.
The unbalanced equation for the reaction of copper with concentrated nitric acid is shown below.
.........Cu + ...HNO_3 → ....$Cu(NO_3)_2$ + ...NO_2 + ...H_2O

What is the number of moles of HNO_3 that react with 1 mole of Cu?

A 2
B 3
C 4
D 6

Your answer ☐ **[1]**

59. What is the formula of silver carbonate?

A $AgCO_3$
B $Ag(CO_3)_2$
C Ag_2CO_3
D Ag_3CO_3

Your answer ☐ **[1]**

60. In the laboratory, acid spills can be cleaned up and made safe by spreading anhydrous sodium carbonate over the spill to neutralise the acid.

A student accidentally spills 50.0 cm^3 of 2.00 mol dm^{-3} HC*l* (aq) on the bench.

What is the minimum mass of anhydrous sodium carbonate required to neutralise the acid?

A 4.15 g
B 5.30 g
C 8.30 g
D 10.6 g

Your answer ☐ **[1]**

61. Phosphine, PH_3, is a gas formed by heating phosphorous acid, H_3PO_3, in the absence of air.

$$4H_3PO_3(s) \rightarrow PH_3(g) + 3H_3PO_4(s)$$

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]**

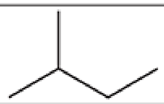
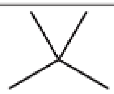
ii. When exposed to air, phosphine spontaneously ignites, forming P_4O_{10} and water.

Construct an equation for this reaction.

[1]

62(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.

Compound D

Equation **[2]**

63. The electron configuration of element **X** is: $1s^2 2s^2 2p^6 3s^2 3p^4$

What is the formula of a compound formed when sodium reacts with element **X**?

A Na**X**
B Na$\mathbf{X}_2$
C Na_2**X**
D $Na_2\mathbf{X}_3$

Your answer **[1]**

64.
Succinic acid is esterified by ethanol, C_2H_5OH, 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**.

$$K_c = \frac{n((CH_2COOC_2H_5)_2) \times n(H_2O)^2}{n((CH_2COOH)_2) \times n(C_2H_5OH)^2}$$ **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]**

65(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.

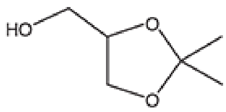
Complete combustion of 1.71 g of compound **N** produces 2.97 g of CO_2 and 1.62 g of H_2O. The relative molecular mass of compound **N** is 76.0.

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

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). The relative molecular masses and boiling points of some fuels are shown in **Table 22.1**.

Fuel	Relative molecular mass	Boiling point / °C
hexane	86	69
pentan-1-ol	88	138
heptane	100	98

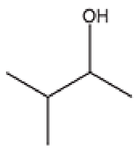
Table 22.1

Write an equation for the incomplete combustion of heptane.

[1]

66(a). This question is about reactions of organic compounds containing carbon, hydrogen and oxygen.

A chemist investigates two reactions of alcohol **A**, shown below.



alcohol A

i. What is the systematic name of alcohol **A**?

[1]

ii. What is the structural formula of alcohol **A**?

[1]

iii. The chemist heats alcohol **A** with an acid catalyst to form a mixture containing **two** alkenes.

Draw the structures of the **two** alkenes formed in this reaction.

[2]

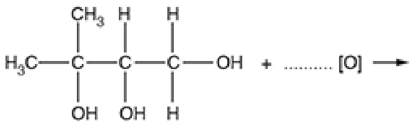
iv. The chemist heats alcohol **A** with sodium chloride and sulfuric acid.

Construct a balanced equation for this reaction.
Show structures for the organic compounds in your equation.

[2]

(b). Compound **B**, shown below, is refluxed with excess acidified potassium dichromate(VI) to form a single organic product.

Complete the equation for this reaction.



compound B

[2]

67. * 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]**

68. In the Periodic Table, element **X** is in Group 2 and element **Y** is in Group 15 (5).

What is the likely formula of an ionic compound of **X** and **Y**?

A $\mathbf{X_2Y_5}$
B $\mathbf{X_2Y_3}$
C $\mathbf{X_3Y_2}$
D $\mathbf{X_5Y_2}$

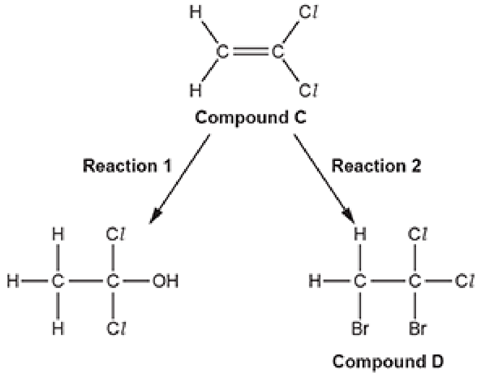
Your answer [1]

69. Which statement about ammonium carbonate is **not** correct?

A It reacts with $Ba(NO_3)_2(aq)$ to form a white precipitate.
B It effervesces with dilute nitric acid.
C It release an alkaline gas with warm NaOH(aq).
D It has the formula NH_4CO_3.

Your answer [1]

70(a). Two reactions of compound **C** are shown in the flowchart below.



State the reagents and conditions for **reaction 1**.

---

[1]

(b). In **reaction 2**, compound **C** reacts with bromine to form compound **D**.

i. Give the systematic name of compound **D**.

[1]

ii. Outline the mechanism for **reaction 2**.

Include curly arrows, charges and relevant dipoles.

[3]

(c). Compound **C** forms an addition polymer **E**.

i. Write a balanced equation for this reaction.

Show displayed formulae.

[2]

ii. State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of waste polymer **E**.

Advantage

Disadvantage

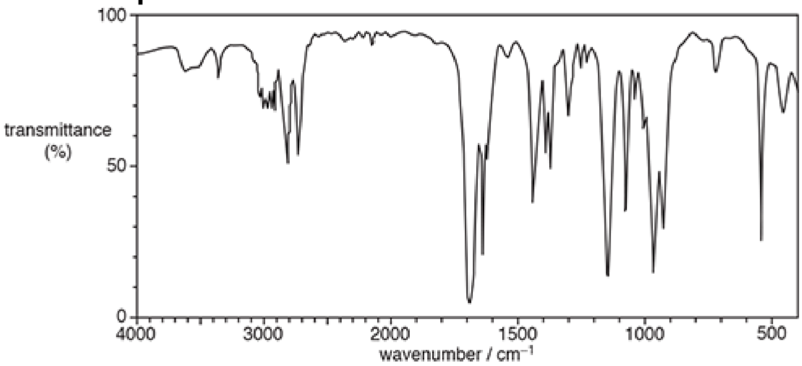
[2]

71. * Compound **F** is a *trans* stereoisomer which is a useful intermediate in organic synthesis.

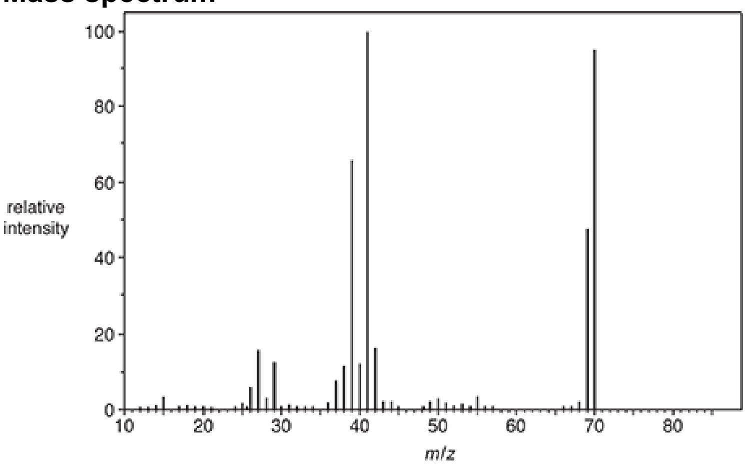
The results of elemental and spectral analysis of compound **F** are shown below.

Percentage composition by mass: C, 68.6 %; H, 8.6 %; O, 22.8 %.

Infrared spectrum



Mass spectrum



In the mass spectrum, the peak with the greatest relative intensity is caused by the loss of a functional group from the molecular ion of compound **F**.

Determine the structure of compound **F**.

Explain your reasoning and show your working.

[6]

72. 'Enthalpy change of vaporisation' is the enthalpy change when one mole of a substance changes from a liquid to a gas at its boiling point.

i. Write an equation, including state symbols, to represent the enthalpy change of vaporisation of bromine.

[1]

ii. Suggest whether the enthalpy change of vaporisation of bromine is exothermic or endothermic.

Explain your answer.

[1]

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

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

$1s^2$ [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]

74(a). A student carries out an experiment to identify an unknown carbonate.

- The student weighs a sample of the solid carbonate in a weighing bottle.
- The student tips the carbonate into a beaker and weighs the empty weighing bottle.
- The student prepares a 250.0 cm^3 solution of the carbonate.
- The student carries out a titration using 25.0 cm^3 of this solution measured using a pipette with 0.100 mol dm^{-3} hydrochloric acid in the burette.

The student carries out the final part of the experiment by adding 0.100 mol dm^{-3} hydrochloric acid to a burette and performing a titration using a 25.0 cm^3 sample of the aqueous carbonate.

The student reads the burette to the nearest 0.05 cm^3.

The diagrams below show the initial burette reading and the final burette reading.

initial reading		final reading	

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.

$$M_2CO_3(aq) + 2HCl(aq) \rightarrow 2MCl(aq) + CO_2(g) + H_2O(l)$$

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

$n(M_2CO_3)$ = ...mol **[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]

75. 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.

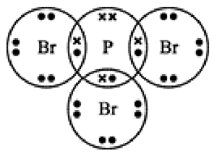
i. Write an equation for this reaction.

[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]

76. Aluminium is reacted with ethanoic acid.

i. The unbalanced equation for the reaction is shown below.

Balance the equation.

……. Al (s) + ……. CH_3COOH(aq) → ……. $(CH_3COO)_3Al$ (aq) + …… H_2(g)

[1]

ii. This reaction is a redox reaction.

Deduce which element has been oxidised and which element has been reduced, and state the changes in oxidation number.

Element oxidised: .... oxidation number change: from .... to ....

Element reduced: .... oxidation number change: from .... to ....

[2]

77. 2-chloropropene can be polymerised to form poly(2-chloropropene).

i. Write a balanced equation for the formation of this polymer.
The equation should include the structure of the repeat unit of the polymer.

[2]

ii. After their useful life, waste polymers can be disposed of by combustion.

State **one** particular problem with disposal of poly(2-chloropropene) by combustion.

[1]

78. Fig. 22.1 shows first ionisation energies for elements across Period 3.

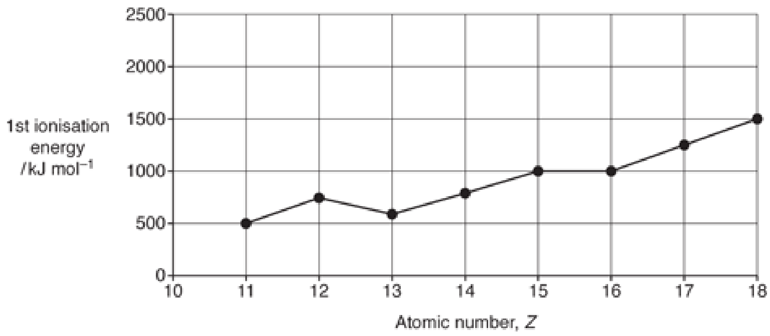


Fig. 22.1

i. Add a point to **Fig. 22.1** for the first ionisation energy of the element with Z = 10.

[1]

ii. Estimate the energy required to form **one** $Na^+(g)$ ion from one Na(g) atom.
Give your answer in kJ, in standard form, and to **two** significant figures.

energy = ... kJ **[1]**

iii. Explain why the first ionisation energies in **Fig. 22.1** show a general increase across Period 3 (Na–Ar).

[3]

iv. Explain why the general increase in first ionisation energies across Period 3 is **not** followed for Mg (*Z* = 12) to A*l* (*Z* = 13).

[2]

79. Barium nitride is formed when barium is heated with nitrogen.

i. Complete the electron configuration of a nitride ion.

$1s^2$ [1]

ii. Solid barium nitride is reacted with water, forming an alkaline solution **A** and an alkaline gas **B**.

Identify **A and B**.

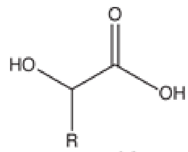
Write an equation, including state symbols, for the reaction.

A

B

[4]

80. The structural formula of compound **A** is shown below.



compound A

Two reactions of compound **A** are carried out.

Suggest an equation for each reaction and state the type of reaction.

In your equations, draw structures for organic compounds.
You can use R for the alkyl group.

i. Magnesium ribbon is added to a solution of compound **A**.
Gas bubbles are seen and the magnesium slowly dissolves.

Equation

Type of reaction [3]

ii. Compound **A** is heated with a few drops of concentrated sulfuric acid as a catalyst.
A cyclic 'dimer' of compound **A** forms.

Equation

Type of reaction [3]

81. Solutions of hydrogen peroxide decompose slowly into water and oxygen:

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

This reaction is catalysed by manganese dioxide, $MnO_2(s)$.

Standard electrode potentials are shown below.

$O_2(g) + 2H^+(aq) + 2e^-$	$\rightleftharpoons$	$H_2O_2(aq)$	$E^\theta = +0.70$ V
$MnO_2(s) + 4H^+(aq) + 2e^-$	$\rightleftharpoons$	$Mn^{2+}(aq) + 2H_2O(l)$	$E^\theta = +1.51$ V
$H_2O_2(g) + 2H^+(aq) + 2e^-$	$\rightleftharpoons$	$2H_2O(l)$	$E^\theta = +1.78$ V

Using the electrode potentials, explain how MnO_2 is able to act as a catalyst for the decomposition of hydrogen peroxide.

Your answer should include relevant equations.

[4]

82(a). This question is about alcohols.

Construct an equation for the complete combustion of an unsaturated alcohol with 5 carbon atoms.

[1]

(b). Butan-1-ol can be oxidised to form two different organic products, depending on the reaction conditions used.

Describe both oxidation reactions of butan-1-ol.

For each reaction include

- the structure of the organic product
- a balanced equation

- the essential reaction conditions.

In your equations you may use [O] to represent the oxidising agent.

[5]

83. Myrcene, $C_{10}H_{16}$, is a naturally occurring hydrocarbon containing more than one carbon-carbon double bond.

myrcene

i. Reaction of 204 mg of myrcene with hydrogen gas produces a saturated alkane.

Calculate the volume of hydrogen gas, in cm^3 and measured at RTP, needed for this reaction.

Show your working.

volume = ... cm^3 **[2]**

ii. ß-Carotene is a naturally occurring unsaturated hydrocarbon found in carrots.
A ß-carotene molecule contains 40 carbon atoms, has two rings, and a branched chain.

0.0200 mol of ß-carotene reacts with 5.28 dm^3 of hydrogen gas to form a saturated hydrocarbon.

Using molecular formulae, construct a balanced equation for this reaction.

Include relevant calculations and reasoning.

Equation .... **[4]**

84. Which calcium compound contains the **greatest** percentage by mass of calcium?

A calcium carbonate
B calcium nitrate
C calcium hydroxide
D calcium sulfate

Your answer [ ] **[1]**

85(a). A student was provided with five compounds: an aldehyde, a ketone, a carboxylic acid and two esters. The student decides to identify the type of compound by carrying out some chemical tests.

Suggest chemical tests to identify the carboxylic acid and aldehyde.

For each test, include essential reagent(s), observation(s) and a balanced equation.

In your equations, use 'R' for the alkyl group.

i. Test for carboxylic acid.

Reagent(s)
....

Observation(s)
....

Equation

[2]

ii. Test for aldehyde.

Reagent(s)
....

Observation(s)
....

Equation

[2]

(b). Suggest a chemical test to distinguish the ketone from the two esters.

Reagent(s) ....

Observation(s) ....

[1]

(c). The student wants to confirm that the other two compounds are esters. Unfortunately there is no direct test for an ester group.

The esters are $CH_3COOC(CH_3)_3$ and $(CH_3)_3CCOOCH_3$.

The student plans the following:

- hydrolyse the two esters using aqueous sodium hydroxide.
- separate the hydrolysis products.
- carry out tests on the hydrolysis products.

i. Write an equation for the hydrolysis of one of the two esters with aqueous sodium hydroxide.

Show the structures for the organic compounds.

[2]

ii. Suggest a chemical test on the hydrolysis products that would allow the two esters to be identified.

Write an equation for one reaction that takes place.

Show the structures for the organic compounds.

Reagent(s)
....

Observation(s)
....

Equation

[2]

iii. The student thought that NMR spectroscopy could be used to identify the two esters without the need to carry out chemical tests.

The esters are $CH_3COOC(CH_3)_3$ and $(CH_3)_3CCOOCH_3$.

Explain whether the student is correct for ^{13}C and ^{1}H NMR spectroscopy. Your answer should also clearly state any differences between the spectra of the two esters.

[3]

(d). The ketone and aldehyde provided to the student both contain five carbon atoms.

The ^{1}H NMR spectrum of the aldehyde contains two singlet peaks only:
a large peak at δ = 1.2 ppm and smaller peak at δ = 9.6 ppm.

Suggest **all** possible structures for the ketone and identify the aldehyde.

Show **all** your reasoning.

[5]

86. The use of some haloalkanes, such as chlorotrifluoromethane, has been banned as they form C*l* • radicals which break down ozone.

i. Construct an equation to show the formation of C*l* • radicals from chlorotrifluoromethane.

[1]

ii. Ozone is broken down by C*l* • 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 C*l* • radicals can breakdown 135 kg of O_3.

Calculate the number of O_3 molecules removed by one C*l* • radical.

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

number of O_3 molecules = ... **[3]**

87(a). This question is about reactions of sulfur compounds.

A student neutralises aqueous sulfuric acid, $H_2SO_4(aq)$, with aqueous sodium hydroxide, NaOH(aq), to determine the enthalpy change of neutralisation, $\Delta_{neut}H$.

i. Define the term *enthalpy change of neutralisation* and write the ionic equation for the this change. Include state symbols.

[2]

ii. Write a full equation for the complete neutralisation of H_2SO_4 with NaOH(aq).
State symbols are **not** required.

.... **[1]**

iii. In their experiment, the student follows the method below.

- Add 50.0 cm^3 of 1.50 mol dm^{-3} NaOH(aq) to a polystyrene cup.
- Measure out 25.0 cm^3 of 1.50 mol dm^{-3} H_2SO_4(aq).
- Measure the initial temperature of both solutions.
- Add the H_2SO_4(aq) to the NaOH(aq) in the polystyrene cup, stir the mixture, and record the maximum temperature reached.

Results

Initial temperature of both solutions	22.0 °C
Maximum temperature of mixture	35.5 °C

Calculate $\Delta_{neut}H$, in kJ mol^{-1}.

Assume that the density and specific heat capacity of all solutions are the same as for water.

$\Delta_{neut}H$ = ... kJ mol^{-1} **[3]**

(b). Much of the sulfur required for production of sulfuric acid is obtained from sulfur impurities in natural gas, such as hydrogen sulfide, H_2S.

The H_2S is converted into sulfur in two steps.

Step 1: Some of the H_2S is reacted with oxygen to form sulfur dioxide, SO_2.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

Step 2: The remaining H_2S is reacted with the SO_2 to produce sulfur.

$$2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(g)$$

i. Construct the overall equation for the two steps above.

[1]

ii. A natural gas supply contains 16.0% H_2S by volume.
The $H_2S(g)$ in 1.50×10^8 dm^3 of this natural gas supply, measured at RTP, is processed into sulfur with an overall percentage yield of 95.0%.

Calculate the mass of sulfur, in g, obtained from 1.50×10^8 dm^3 of natural gas supply.

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

mass of sulfur = ... g **[3]**

(c). The enthalpy change for the equation in **step 2** is shown below.

$$2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(g) \qquad \Delta H = -145.6 \text{ kJ mol}^{-1}$$

Standard entropies, *S*, and enthalpy changes of formation, $\Delta_f H$, are given in the table.

Substance	$H_2S(g)$	$SO_2(g)$	S(s)	$H_2O(g)$
***S* / J mol⁻¹ K⁻¹**	205.7	248.1	31.8	188.7
$\Delta_f H$ / kJ mol⁻¹	−20.6		0	−241.8

i. Calculate ΔG at 25 °C, and explain whether the reaction in **step 2** is feasible at 25 °C.

Calculate the temperature, in K, at which the feasibility changes.

Show your working and explain your reasoning.

[5]

ii. Calculate $\Delta_f H$ for $SO_2(g)$.

$\Delta_f H$ for $SO_2(g)$ = ...kJ mol^{-1} **[2]**

88(a). Hydrated copper(II) methanoate, $Cu(HCOO)_2 \cdot xH_2O$, is a copper salt.

A student carries out the procedure below to prepare $Cu(HCOO)_2 \cdot xH_2O$ and to determine the value of *x* in its formula.

Step 1
The student prepares $Cu(HCOO)_2 \cdot xH_2O$ by reacting a copper compound with aqueous methanoic acid to form $Cu(HCOO)_2(aq)$ and allowing the solvent to evaporate.

Step 2
The student dissolves 2.226 g of $Cu(HCOO)_2 \cdot xH_2O$ in water and makes up the solution to 250.0 cm^3.

Step 3
Using a pipette, the student adds 25.0 cm^3 of this solution to a conical flask followed by an excess of KI(aq).

The $Cu^{2+}(aq)$ ions react to form a precipitate of copper(I) iodide and $I_2(aq)$.
In this reaction, 2 mol Cu^{2+} form 1 mol I_2.

Step 4
The student titrates the iodine in the resulting mixture with 0.0420 mol dm^{-3} $Na_2S_2O_3$ (aq).

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

23.5 cm^3 0.0420 mol dm^{-3} $Na_2S_2O_3$ (aq) is required to reach the end point.

Complete the electron configuration of copper in

$Cu(HCOO)_2 \cdot xH_2O$: 1s^2 ....
copper(I) iodide: 1s^2 .... **[2]**

(b). Choose a suitable copper compound for **step 1**, and write the full equation for the reaction that would take place to form $Cu(HCOO)_2(aq)$.

State symbols are **not** required.

[1]

(c). Write an ionic equation, including state symbols, for the reaction in **step 3**.

[1]

(d). In **step 4**, the student adds a solution to observe the end point accurately.

Name the solution and state the colour change at the end point.

Solution added:..

Colour change: .... **[2]**

(e). Determine the value of *x* in $Cu(HCOO)_2 \bullet xH_2O$.

Show your working.

[5]

89. Stearic acid, oleic acid and linoleic acid are examples of naturally occurring fatty acids.

Traditional name	Structure	Systematic name
Stearic acid	$C_{17}H_{35}COOH$	Octadecanoic acid
Oleic acid	$C_{17}H_{33}COOH$	Octadec-9-enoic acid
Linoleic acid	$C_{17}H_{31}COOH$	Octadeca-9,12-dienoic acid

Sodium stearate is the salt formed when stearic acid reacts with sodium hydroxide solution.

Write an equation for the formation of sodium stearate.

[1]

90(a). Aqueous lead(II) nitrate, $Pb(NO_3)_2(aq)$, and aqueous potassium iodide, KI(aq), react together.
The equation is shown below.

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

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

The student follows the method outlined below.

- Add 50.0 cm^3 of 1.50 mol dm^{-3} $Pb(NO_3)_2(aq)$ to a polystyrene cup.
- Measure out 50.0 cm^3 of a solution of KI(aq), which is in excess.
- Measure the temperature of both solutions.
- Add the KI(aq) to the polystyrene cup, stir the mixture and record the maximum temperature.

Temperature readings
Initial temperature of both solutions = 19.5 °C
Maximum temperature of mixture = 30.0 °C

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

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

Assume that the density of all solutions and specific heat capacity, *c*, of the reaction mixture is the same as for water.

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

(b). Write an ionic equation for the reaction that the student carries out.

Include state symbols.

.... **[1]**

(c). The 50.0 cm^3 of KI(aq) used inthe experiment contains 10% more KI than is needed to react with 50.0 cm^3 of 1.50 mol dm^{-3} $Pb(NO_3)_2(aq)$.

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

Calculate the concentration, in mol dm^{-3}, of KI that the student used.

concentration of KI =.. mol dm^{-3} **[2]**

91. What is the formula of ammonium sulfide?

A NH_4S
B NH_4SO_4
C $(NH_4)_2S$
D $(NH_4)_2SO_4$

Your answer

[1]

92(a). Zinc carbonate, $ZnCO_3$, reacts with dilute hydrochloric acid.

A student reacts a sample of $ZnCO_3$ with an excess of dilute hydrochloric acid in a test-tube.

i. Describe what the student would see during this reaction.

[1]

ii. Write the equation for the reaction between $ZnCO_3$ and dilute hydrochloric acid.

[1]

(b). Magnesium will undergo redox reactions with aqueous salts of less reactive metals.

i. A student reacts magnesium with aqueous copper(II) sulfate.

$$Mg(s) + CuSO_4(aq) \rightarrow Cu(s) + MgSO_4(aq)$$

Explain, in terms of **numbers** of electron transferred, the redox processes taking place in this reaction.

[2]

ii. The student also noticed that the magnesium started fizzing.

The student thought the fizzing was due to the magnesium reacting with water in the mixture.

Write the equation for the reaction of magnesium with water.

Include state symbols.

[2]

(c). Compounds of calcium have many uses.

i. Identify a compound of calcium that could be used to convert a soil pH from 5.8 to 7.5.

[1]

ii. Calcium phosphide, Ca_3P_2, is an ionic compound used in rat poison.

Calcium phosphide can be prepared by reacting calcium metal with phosphorus, P_4.

Write the equation for the reaction of calcium with phosphorus to form calcium phosphide.

[1]

iii. Draw a '*dot-and-cross*' diagram to show the bonding in calcium phosphide, Ca_3P_2.

Show **outer** electrons only.

[2]

93. Fluorine forms several compounds with sulfur and with oxygen.

i. Give the **formula** and the **name** of the compound formed between fluorine and sulfur which has octahedral molecules.

Formula ....

Name ....

[1]

ii. Fluorine reacts with aqueous sodium hydroxide to form the oxide F_2O.
Two other products are also formed. One product is an ionic compound with a relative formula mass of 42.0.

Construct a balanced equation for this reaction.

[2]

94. A student carries out test-tube experiments to prove the trend in reactivity of halogens.

The student is provided with the following solutions:

- bromine water
- aqueous iodine
- aqueous barium chloride
- aqueous magnesium bromide
- aqueous calcium iodide.

Chlorine gas and chlorine water are **not** available.

The student carries out the **minimum** number of test-tube experiments using these solutions in the presence of cyclohexane (an organic solvent).

- State the solutions that need to be added together in order to prove the trend in reactivity of the halogens, using the **minimum** number of test-tube experiments.
- Describe the colour seen in the organic solvent at the end of each test-tube experiment.
- Write an ionic equation for **one** reaction that takes place.

[5]

95. Gallium, atomic number 31, is in Period 4 of the Periodic Table. Gallium is a Group 3 element.

Predict the formula of a gallium ion.

[1]

96. Nitrogen forms several different oxides.

N_2O is a useful anaesthetic and NO has been linked to the depletion of ozone in the stratosphere.

The standard enthalpy changes of formation of N_2O and NO are given in the table.

Compound	**$\Delta_f H^{\ominus}$ / kJ mol^{-1}**
N_2O (g)	+ 82.0
NO (g)	+ 90.2

i. Explain, in terms of bond breaking and bond making, why the enthalpy change of formation of NO is endothermic.

[1]

ii. Draw a fully labelled enthalpy profile diagram to represent the enthalpy change of formation of N_2O.

The formulae, with state symbols, of the reactants and products should be included as part of the diagram.

You are **not** expected to show the activation energy for the reaction.

[2]

97(a). Chromite is the main ore of chromium. The chromium-containing compound in chromite is $Fe(CrO_2)_2$. The percentage of chromium in a sample of chromite can be determined using the method below.

Step 1

A 5.25 g sample of chromite ore is heated with sodium peroxide, Na_2O_2.

$$2Fe(CrO_2)_2 + 7Na_2O_2 \rightarrow 2NaFeO_2 + 4Na_2CrO_4 + 2Na_2O$$

Water is added to the resulting mixture.
Na_2CrO_4 dissolves in the water forming a solution containing CrO_4^{2-} ions.

Step 2

The mixture from **Step 1** is filtered and the filtrate is made up to 1.00 dm^3 in a volumetric flask.
A 25.0 cm^3 sample of this alkaline solution is pipetted into a conical flask and an excess of aqueous potassium iodide is added.

- A redox reaction takes place between I^- ions, CrO_4^{2-} ions and H_2O.
- In this reaction 1 mol CrO_4^{2-} forms 1.5 mol I_2.

Step 3

The resulting mixture is titrated with 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3(aq)$ to estimate the I_2 present:

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The average titre of $Na_2S_2O_3(aq)$ is 25.5 cm^3.

In **Step 1** Na_2O and $NaFeO_2$ react with water forming an alkaline solution containing a brown precipitate. This is **not** a redox reaction.

Write equations for:

- the reaction of Na_2O with water
- the reaction of $NaFeO_2$ with water.

[2]

(b). Determine the percentage, by mass, of chromium in the ore.

Give your answer to **one** decimal place.

[6]

(c). This part refers to **Step 2** of the method.

In the redox reaction between I^- ions, CrO_4^{2-} ions and H_2O:

- CrO_4^{2-} ions, are reduced to chromium(III) ions, Cr^{3+}
- I^- ions are oxidised to iodine, I_2
- Construct an overall equation for the redox reaction and write half equations for the oxidation and reduction.

Overall equation:

Half equations:

[3]

98. A molecule of an alkane has 24 carbon atoms.

State the empirical formulae of this alkane.

[1]

99. This question is about compounds of Group 3 elements.

Aluminium will combine directly with fluorine.

Write the equation for the reaction between aluminium and fluorine.

[1]

100. A chemist carries out reactions of barium and barium nitride, Ba_3N_2.

Reaction 1	Barium is reacted with water.
Reaction 2	Barium nitride is reacted with water, forming an alkaline solution and an alkaline gas.
Reaction 3	Barium is reacted with an excess of oxygen at 500°C, forming barium peroxide, BaO_2.

i. Write equations for **Reaction 1** and **Reaction 2**.

Ignore state symbols.

Reaction 1: ....

Reaction 2: ....

[3]

ii. Predict the structure and bonding of Ba_3N_2.

[1]

iii. BaO_2 formed in **Reaction 3** contains barium and peroxide ions.
The peroxide ion has the structure $[O-O]^{2-}$.

Suggest a '*dot-and-cross*' diagram for BaO_2.

Show outer shell electrons only.

[1]

101. A salt used as a fertiliser has the empirical formula $H_4N_2O_3$.

Suggest the formulae of the ions present in this salt.

[2]

102. This question looks at neutralisation reactions.

A student carries out an experiment to determine the enthalpy change for a neutralisation reaction.

The student measures out 35.0 cm^3 of 2.40 mol dm^{-3} KOH and 35.0 cm^3 of 1.20 mol dm^{-3} H_2SO_4.
The temperature of each solution is 19.5 °C.

The student mixes the solutions. The KOH is all neutralised and the maximum temperature reached is 36.0 °C.

i. Write the overall equation for the reaction that takes place.

[1]

ii. Calculate the enthalpy change for the reaction between 1 mol KOH and 1 mol HCl.

Assume that the density of the mixture is 1.00 g cm^{-3} and that the specific heat capacity for the solution is the same as for water.

ΔH = ... kJ **[3]**

iii. Explain, why the answer to **(ii)** is the enthalpy change of neutralisation.

[1]

iv. In this experiment, the student uses a thermometer with an uncertainty of ±0.5 °C in each reading.

Calculate the percentage uncertainty in the temperature rise.

percentage uncertainty = ... % **[1]**

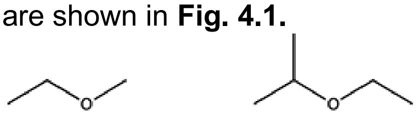
103. Bromine and mercury react with many elements and compounds.

Predict the formula of the compound formed when bromine reacts with aluminium.

[1]

104(a). Ethers are a homologous series of organic compounds containing the R−O−R functional group.

The structures and names of two ethers are shown in **Fig. 4.1.**



methoxyethane 2-ethoxypropane

Fig. 4.1

Draw the **skeletal** formula of the ether, 2-ethoxy-3-methylbutane.

[1]

(b). Ethers can be prepared by nucleophilic substitution of haloalkanes with alkoxide ions, RO^-.

i. Alkoxide ions can be prepared by reacting sodium with an alcohol. A gas is also formed.

Write an equation for the formation of methoxide ions from sodium and an alcohol.

[1]

---

ii. Methoxyethane, shown in **Fig. 4.1**, can be prepared by reacting bromoethane, CH_3CH_2Br, with methoxide ions, CH_3O^-.

Suggest the mechanism for the nucleophilic substitution of CH_3CH_2Br with CH_3O^-.

Show curly arrows, charges, relevant dipoles, and products.

[3]

iii. In this mechanism, explain how CH_3O^- ions have acted as a nucleophile.

State the type of bond fission that takes place.

[1]

(c). 2-Ethoxypropane, shown in **Fig. 4.1**, is analysed by [1]H NMR spectroscopy.

Complete the table to predict the [1]H NMR spectrum of 2-ethoxypropane.
You may **not** need to use all the rows.

Chemical shift, δ/ppm	Relative peak area	Splitting pattern

[4]

(d). In organic reactions, alkoxide ions can also act as a base.

The diagram below shows an incomplete mechanism for the reaction of a diester with methoxide ions, CH_3O^- (**Step 1**), followed by reaction of the intermediate with bromoethane (**Step 2**).

i. For **Step 1**, add curly arrows to show how CH_3O^- reacts with the diester to form the intermediate.
In the box, draw the structure of the organic product formed in **Step 2**.

[3]

ii. Explain how CH_3O^- ions have acted as a base in this mechanism.

[1]

---

105. A redox reaction takes place when copper metal is heated with concentrated sulfuric acid. A blue solution forms and 95.0 cm^3 of a colourless gas is collected, measured at RTP. The gas has a mass of 254 mg.

i. Write the electron configuration, in terms of sub-shells, for a copper atom.

[1]

ii. Suggest the identity of the colourless gas and write an equation for the reaction taking place.

State symbols are **not** required in the equation.

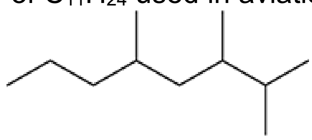
Show your working for calculations.

gas:

equation:

[4]

106(a). Hydrocarbon **D** is a structural isomer of $C_{11}H_{24}$ used in aviation fuel.



hydrocarbon D

Name hydrocarbon **D**.

[1]

(b). When used in a jet engine, hydrocarbon **D** undergoes complete combustion as shown in the equation below:

$C_{11}H_{24} + 17O_2 \rightarrow 11CO_2 + 12H_2O$ **hydrocarbon D**

i. During a typical flight in the upper atmosphere:
   - the aircraft burns 80.4 tonnes of hydrocarbon **D**
   - the temperature outside the aircraft is −55 °C
   - the pressure is 26.5 kPa

Calculate the volume, in m^3, of CO_2 released during a typical aircraft flight.

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

volume of CO_2 = ... m^3 **[5]**

ii. Exhaust gases from an aircraft engine contain nitrogen monoxide.

Write an equation for the formation of nitrogen monoxide in an aircraft engine.

[1]

107(a). This question looks at groups in the periodic table.

Calcium and strontium are Group 2 metals. They both react with water.
A chemist reacts 0.200 g of strontium with 250 cm^3 water, leaving a colourless solution containing strontium ions. The volume remains at 250 cm^3.

i. Write an equation for the reaction between strontium and water.

Include state symbols.

[1]

ii. Calculate the concentration, in mol dm^{-3}, of strontium ions in the resulting solution.

concentration of strontium ions = ...mol dm^{-3} **[2]**

iii. A student plans to carry out this experiment using 0.200 g of calcium instead of 0.200 g of strontium. Predict the difference, if any, between the volume of gas produced by calcium and strontium. Explain your reasoning and include a calculation in your answer.

[3]

(b). Ionisation energies can provide evidence for electron structure.
Write an equation for the first ionisation energy of chlorine.
Include state symbols.

[1]

(c). The following data shows the first eight successive ionisation energies of an element.

Ionisation energy	1st	2nd	3rd	4th	5th	6th	7th	8th
Energy / kJ mol^{-1}	590	1145	4912	6474	8144	10 496	12 320	14 207

In which group of the periodic table would this element be found?

Use the data to justify your choice.

group:

justification:

[2]

108. Two elements, **A** and **B**, react to form an ionic compound with the formula $\mathbf{A_2B_3}$. In this compound, **A** and **B** both have the electron configuration $1s^22s^22p^63s^23p^6$.

Deduce possible identities of the ions in $\mathbf{A_2B_3}$.

A:

B:

[2]

109.

i. Hydrazine, N_2H_4, is used as a rocket fuel. Hydrazine can be prepared from the reaction of ammonia with sodium chlorate(I). There are two other products in the reaction.

   Write an equation for this reaction.

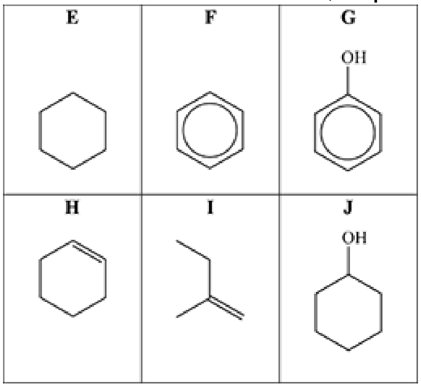
[1]

ii. Using the electron pair repulsion theory, draw a 3-D diagram of a molecule of hydrazine.

   Predict the H–N–H bond angle around each nitrogen atom.

H–N–H bond angle: .... **[2]**

110(a). The organic compounds in the table below can be termed, aliphatic, alicyclic or aromatic.



Identify, using letters **E**, **F**, **G**, **H**, **I**, **J**, the compound(s) which are the following types.

Each response may contain more than one letter.

aliphatic ....

alicyclic ....

aromatic ....

[3]

(b). Compound **I** has one alkyl group.

What is the general formula of alkyl groups?

[1]

(c). Compound **H** can be prepared in an elimination reaction by heating compound **J** with an acid catalyst.

A student carries out this preparation using 7.65 g of compound **J**.

The student obtains 2.05 g of compound **H**.

i. Write an equation for this reaction, using molecular formulae.

Calculate the percentage yield of compound **H**.

Give your answer to **one** decimal place.

percentage yield = ... % **[4]**

ii. Describe a simple test that the student could carry out to confirm the presence of the functional group in compound **H**.

Draw the structure of the organic product from the test.

test: --

organic product =

[2]

111. Haloalkanes can undergo hydrolysis.

A student carries out an experiment to find the relative rate of hydrolysis of 1-chloropropane, C_3H_7Cl, 1-bromopropane, C_3H_7Br, and 1-iodopropane, C_3H_7I.

The student adds 2 cm^3 of ethanol to 2 cm^3 of aqueous silver nitrate to three test tubes labelled **A**, **B** and **C**.

The student adds 5 drops of a different haloalkane to each test-tube in rapid succession and shakes each tube. The student measures the time for a precipitate to form in each test-tube.

The results are shown below.

Test tube	Haloalkane	Time taken for reaction to take place
A	C_3H_7Cl	about half an hour
B	C_3H_7Br	a few minutes
C	C_3H_7I	a few seconds

i. Write an **ionic** equation involving aqueous silver nitrate for formation of **one** of the precipitates.

-- **[1]**

ii. What do the experimental results tell you about the carbon–halogen bond enthalpies?

[1]

iii. How could the student modify their experiment so that it could be completed in less time?

[1]

112. What is the formula of chromium(III) sulfate?

A. Cr_3SO_4
B. $Cr(SO_4)_3$
C. $Cr_2(SO_4)_3$
D. Cr_3SO_3

Your answer ☐

[1]

END OF QUESTION PAPER

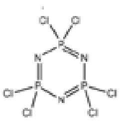
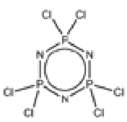
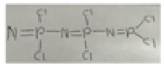
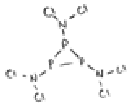
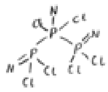
Mark scheme

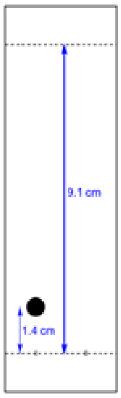
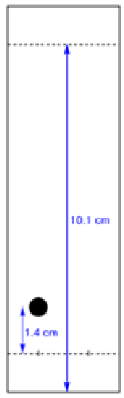
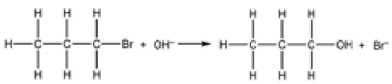
Question			Answer/Indicative content	Marks	Guidance
1			$C_5H_{12}O^+$ 7½ $O_2 \rightarrow$ 5 CO_2 + 6 H_2O CO_2 **AND** H_2O products ✓ Complete equation balanced ✓	2	**ALLOW** multiples e.g. 2 $C_5H_{12}O$ + 15 $O_2 \rightarrow$ 10 CO_2 + 12 H_2O Watch for 15/2 **OR** 7.5 for 7½ **<u>Examiner's Comments</u>** Most candidates identified the correct products of this combustion as CO_2 and H_2O. The second mark was available for a balanced equation but many balanced O_2 with an 8 rather than with 7½. Candidates need to be very careful when writing equations for the combustion of alcohols as it is easy to miss the O atom within the alcohol formula.
			Total	**2**	
2	a	i	$4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓	1	**ALLOW** multiples **ALLOW** $2PH_3 + 4O_2 \rightarrow P_2O_5 + 3H_2O$ **IGNORE** state symbols, even if wrong **<u>Examiner's Comments</u>** Candidates found this question quite challenging, with only about one-third writing a correct equation. The question gave the reactants and products with only the formula of phosphorus(V) oxide having to be worked out. The actual reaction does produce P_4O_{10} but P_2O_5 was shown in almost all equations, and this was acceptable. Various incorrect formulae were seen for phosphorus(V) oxide including PO, PO_2, P_5O, HPO, etc. Unfortunately a significant number of candidates could not balance the equation, despite using correct formulae.
		ii	$6AgNO_3$ + (1)PH_3 + $3H_2O \rightarrow$ 6Ag + (1)H_3PO_3 + $6HNO_3$ ✓	3	**ALLOW** equation with '1' omitted, i.e. $6AgNO_3 + PH_3 + 3H_2O \rightarrow 6Ag + H_3PO_3 + 6HNO_3$ ✓ **BUT DO NOT ALLOW** '0'

			Ag is reduced from +1 to 0 ✓ P is oxidised from -3 to +3 ✓ **IGNORE** oxidation numbers written around equation *Treat as rough working* **IGNORE** reference to electrons *Question states oxidation numbers*		**ALLOW** 1 mark for **BOTH** correct oxidation number changes with 'reduced' and 'oxidised' omitted **OR** 'oxidised and reduced the wrong way round + signs required for +1 and +3 For oxidation numbers, **ALLOW** 1+, 3- and 3+ **Examiner's Comments** This question generated a wide range of responses, testing many important chemical skills. Candidates often used oxidation numbers correctly to show that silver is reduced and phosphorus oxidised, with silver being the easier. Hydrogen was sometimes incorrectly chosen for oxidation. The oxidation number change of +1 to 0 for silver was usually correct although +9 and +11 were common errors for silver in $AgNO_3$, presumably by choosing the oxidation number of nitrogen as -3 or -5. Candidates usually recognised that phosphorus started with an oxidation number of -3 but the oxidation number of +5 was a common error in H_3PO_3. Balancing the equation was the most difficult part of this question with numbers being added almost at random. It is easier to balance equations for redox reactions by balancing the oxidation number changes first. **Assessment for learning** Ag^+ and NO_3^- are among the common ions that students should know (see also Question 4 (c) (i)). For a NO_3^- ion to have a charge of 1–, the oxidation number of nitrogen must be +5. By choosing –5, the charge on NO_3 would be –11 and silver would have an oxidation

					number of +11. This is completely unrealistic and should be rejected as it points to a serious error. The specification states the following: *2.1.5 (a) rules for assigning and calculating oxidation number for atoms in elements, compounds and ions.* This section will have been studied at the start of the two-year course and forms part of the backbone of chemical literacy. For success in chemistry, the ions should be learnt and the rules for assigning oxidation numbers need to be mastered.
	b	i	$3PCl_5 + 3NH_4Cl \rightarrow P_3N_3Cl_6 + 12HCl$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong **<u>Examiner's Comments</u>** This question again required candidates to construct an equation. Candidates were provided with the formula of all species reactants and products except for that of ammonium chloride. Candidates are expected to know that the ammonium ion is NH_4^+ but many incorrect equations showed NH_3Cl. About half the candidates were able to construct a correctly balanced equation with the '12' balancing number for HCl being the hardest part. This links back to the 'assessment for learning' callout added to Question 4 (b) (ii) in this report. As with other questions requiring equations to be written, this question differentiated very well. Writing formulae and balancing equations are fundamentals for mastering chemistry and candidates are advised to practise these skills throughout the course. **Assessment for learning** The specification states the following. ***Formulae and equations***

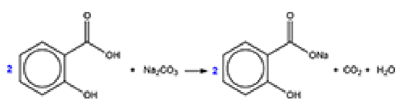
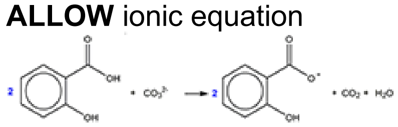
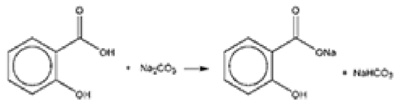
					***2.1.2(a)** the writing of formulae of ionic compounds from ionic charges, including:* i. *prediction of ionic charge from the position of an element in the periodic table* ii. *recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^+* This section will be studied at the start of the two-year course and form the backbone for chemical literacy. For success in chemistry, the common ions should be learnt.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE IF % by mass = 26.72, award 2 marks IF % by mass = 26.7, award 1 mark ---** M_r of $P_3N_3Cl_6$ = 348(.0) ✓ % by mass of P = $\frac{31.0 \times 3}{348} \times 100 = 26.72$ ✓ **2 DP required**	2	**ALLOW** 1 mark total for 26.7 *Question asks for 2 DP* **ALLOW** ECF from incorrect M_r **ALLOW** 1 mark for 8.91 (omission of ×3): $\frac{31.0}{348} \times 100 = 8.91$ **<u>Examiner's Comments</u>** In contrast to equation writing, candidates found this simple calculation far easier with the majority obtaining both marks for 26.72. Common incorrect percentages were 26.7 (wrong number of decimal places) and 8.91 (using 31 rather than 3 × 31 for the numerator).
		iii	(P-N) bond lengths are different ✓ **OR** enthalpy change of hydrogenation is more exothermic (than delocalised structure) **OR** reacts with bromine/electrophiles/by addition	1	**Throughout, ORA** for delocalised structure **IGNORE** C-C bond lengths are different **IGNORE** hydration **ALLOW** decolourises bromine (without a catalyst/halogen carrier) **IGNORE** more reactive without example **IGNORE** alternating single and double bonds **<u>Examiner's Comments</u>**

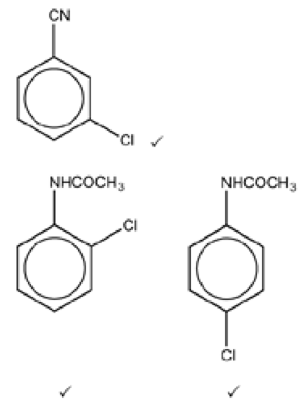
					About half the candidates suggested a range of creditworthy responses with 'different bond lengths' and 'decolorises bromine' being the most common.
		iv	Structure shown with molecular formula $P_3N_3Cl_6$ **1st mark** • Each P bonded to 2 Cl atoms • Each P bonded to N **AND** Cl • Each N has *at least* 2 bonds • Each Cl has 1 bond ✓ **2nd mark (dependent on 1st mark)** • Each N has 3 bonds • Each P has 3 **OR** 5 bonds ✓ **IGNORE** charges Examples for 2 marks 	2	1st mark *Meets criteria for 1st mark*  **ZERO** marks  *N bonded to Cl*  *N atom(s) with 1 bond only* **<u>Examiner's Comments</u>** This was another question where valuable information: *'all N and Cl atoms are bonded to P atoms'* had been provided. Many of the structures seen ignored this information with chlorine often been shown bonded to a nitrogen atom. Nitrogen atoms were often shown with 1 bond only and chlorine atoms in the ring structure with 2 or more bonds. Most structures contained 6 or 3-membered rings. This was a difficult question, requiring candidates to use the supplied information to come up with realistic structures that met chemical bonding rules. Only about a quarter of candidates could be given any mark. The Kekulé theme in Questions 4 (c) (i) - (iv) should have prompted candidates that a Kekulé structure was likely here. Several other structures were allowed providing that they met normal chemistry bonding rules

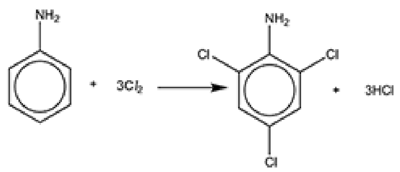
			Total	10	
3		i	$R_f \sim \frac{1.4}{9.1}$ in cm **OR** $\frac{14}{91}$ in mm = **0.15** ✓ *Working required* ***Check for ~ 9.1 as denominator***  	1	**ALLOW** 0.12 - 0.18 (i.e. ±0.03) **DO NOT ALLOW** $\frac{1.4}{10.1}$ = 0.14 ***10.1** measured from bottom of plate to solvent front*  **<u>Examiner's Comments</u>** Candidates are well versed with calculating an R_f value, with nearly all candidates obtaining a value in the acceptable range of 0.12-0.18.
		ii	 Correct balanced equation **ALLOW** OH- above the arrow **DO NOT ALLOW** if a **CON** reagent is present, e.g. an acid For OH- and Br- **ALLOW** KOH and KBr **OR** NaOH and NaBr **BUT DO NOT ALLOW** K-OH *implies covalent bond*	1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW Missing H atoms** **DO NOT ALLOW** H_2O and HBr *Question asks for **alkaline** hydrolysis* **DO NOT ALLOW** C_3H_7, i.e. C_3H_7Br **OR** C_3H_7OH *Structure asked for in Question* **IGNORE** connectivity, e.g. **ALLOW**  **BUT DO NOT ALLOW —HO** **<u>Examiner's Comments</u>** This question was answered well by candidates, with most showing correct structures for the organic reactant and its product, propan-1-ol, and skeletal

					formulae mostly used. The question asked for an equation for alkaline hydrolysis and candidates were expected to use an alkali. Acceptable answers would include NaOH/KOH and NaBr/KBr, or OH^- and Br^-. Equations including H_2O and HBr were not given a mark, a common error for alkaline hydrolysis.
		iii	**Difference** propan-1-ol/product/bottom spot is smaller **OR** 1-chloropropane/reactant/top spot bigger ✓ **Reasons** propan-1-ol/product/bottom spot is smaller C-Cl bond is stronger than C-Br **AND** 1-chloropropane reacts slower/is less reactive ✓ **Use of propan-1-ol** shows **formation** of propan-1-ol **OR** shows when reaction has **finished** **OR** monitors **course/progress** of reaction ✓	3	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF and ORA throughout** --- **IGNORE** references to halogens as elements: *i.e.* chlorine is less reactive than bromine etc. **DO NOT ALLOW** chloride, bromide **DO NOT ALLOW** 1-chloropropane has larger bond enthalpy *C-Cl bond required* **IGNORE** 1-chloroproane has different R_f value **IGNORE** 'as a control' **OR** 'as a comparison' .... with no further explanation **Examiner's Comments** This novel question assessed whether candidates realised why chemists used TLC when carrying out organic reactions. A good response would identify the following key features after 20 minutes: • The C-C*l* bond energy is greater than C-Br and so the reaction would be slower. • The haloalkane spot would be larger and the propan-1-ol spot smaller. • The propan-1-ol is spotted on the chromatogram to monitor the progress of the reaction. The question differentiated very well between candidates, but many did not seem to know where to start with many candidates not scoring any marks. This suggested that candidates recognised

					chromatography as a technique but did not appreciate its relevance in organic chemistry. Some candidates referred to pigments, recalling their early chromatography experiments in finding the colours in ink.
			Total	**5**	
4		i	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ ✓	1	***ALL** 3 state symbols required* **Examiner's Comments** Candidates were required to write a straightforward ionic equation that they would have encountered many times during the A Level Chemistry course. It was surprising that only just over half the candidates produced an equation that could be given. Common errors included the following. • Omission of state symbols or incorrect state symbols, especially (aq) in AgC*l*(s). • Inclusion of nitrate ions or use of $AgNO_3$ instead of Ag^+. • An equation using Cl_2 and forming $AgCl_2$. Some candidates used the ideal gas equation to determine the moles of hydrogen, choosing suitable values for temperature and pressure. This approach was allowed, although the exercise would have wasted candidate time compared to the much simpler division by 24 for using RTP, which is stated in the question.
		ii	***n*($AgNO_3$) 1 mark** $= 2.50 \times 10^{-2} \times 60.0/1000 = 1.5(0) \times 10^{-3}$ (mol) ✓ **Essential mark** **Formula 2 marks** **Ratio** 5.00×10^{-4} mol **A** contains $1.5(0) \times 10^{-3}$ mol Cl **OR** ratio A : Cl = $1.5(0) \times 10^{-3} \div 5.00 \times 10^{-4}$ = 1 : 3 ✓	3	**Check equation from 2b(i) at top of response** --- **ALLOW** 1:3 or 3:1 ratio seen anywhere, e.g. XCl_3 **ALLOW ECF** from formula of silver chloride in **2b(i)** e.g. From $AgCl_2$ *n*(Cl) = **2** × $1.5(0) \times 10^{-3} = 3.(00) \times 10^{-3}$ (mol) ratio = 1 : 6 Formula = SCl_6

			Formula = $AlCl_3$ ✓ Automatically subsumes 1:3 ratio mark ✓ **ALLOW** Al_2Cl_6 **ALLOW** PCl_3		**Examiner's Comments** Most candidates determined the moles of $AgNO_3$ and hence Ag^+ as 1.50×10^{-3} mol. This was given 1 mark, but candidates then needed to use this amount to predict the identity of compound **A**. Most candidates could not see the way forward and many received only 1 mark. Many candidates had worked out 'something' from the supplied data, without knowing where this initial step would take them. Candidates needed to spot that the ratio of the element : C*l* in compound **A** was 5×10^{-4} : 1.50×10^{-3} or 1 : 3. The correct formula of A*l*C*l*$_3$ then follows. MgC*l*$_2$ was a common error obtained by subtracting 5×10^{-4} from 1.50×10^{-3} to obtain a 1 : 2 ratio. This question would be a good exercise for improving the application skills of candidates.
			Total	**4**	
5		i	**Reaction with H_2SO_4** $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$ ✓ **Reaction with excess G**  Correct organic product structure ✓ Correct balanced equation ✓	3	**ALLOW** multiples in both equations **IGNORE** state symbols **ALLOW** $Na_2CO_3 + 2H_2SO_4 \rightarrow 2NaHSO_4 + CO_2 + H_2O$ **ALLOW** ionic equation $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ **ALLOW** H_2CO_3 instead of $CO_2 + H_2O$ **ALLOW** $-COO^-$ (Na^+) for product structure mark **ALLOW** ionic equation  **ALLOW**  **ALLOW** H_2CO_3 instead of $CO_2 + H_2O$ **ALLOW** correct Kekulé representation of benzene **Examiner's Comments** Another fairly challenging question, however most secured at least one mark for giving an equation for the reaction of sulfuric acid with sodium carbonate. Less confident candidates struggled to gain any marks as they were unable to give correct

					formula for sodium sulfate, giving $NaSO_4$ for example. Although many attempted the equation showing the reaction of compound **G** with sodium carbonate, only some correctly identified that only the carboxyl group would react, not the phenol. A small minority of students were able to balance the second equation gaining all 3 marks.
		ii	(NaOH) reacts with phenol / -OH (in compound G / H) **OR** (NaOH) would hydrolyse the ester / compound H	1	**IGNORE** comment about whether it improves or not **DO NOT ALLOW** (NaOH) reacts with alcohol **<u>Examiner's Comments</u>** The best responses correctly identified that using sodium hydroxide was not an improvement and explained this either bystating that it would react with the phenol group or hydrolyse the ester group in compound **H**. However, most candidates appeared not to consider a reaction with **H** in their answer. Many focused on the neutralisation of sulfuric acid in a similar way to sodium carbonate and gave responses such as: • stronger base • no effervescence so harder to see when completely reacted • no CO_2 produced so easier/safer/higher atom economy/less waste • requires double the moles compared to Na_2SO_4 to react
•			**Total**	**4**	
6		i		3	**IGNORE** additional copies of the same structures **IGNORE** connectivity to CN and $NHCOCH_3$ in products. **IGNORE** HCl / H^+ **IGNORE** multisubstituted products **ALLOW** protonation of $NHCOCH_3$ group i.e. $NH_2^+COCH_3$ **ALLOW ECF** small slips on $NHCOCH_3$

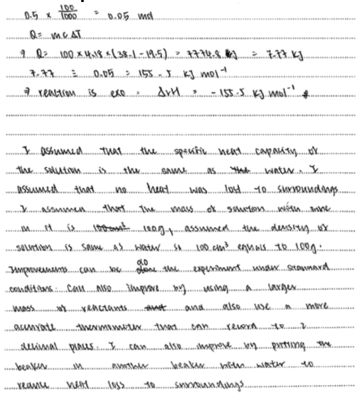
					e.g. extra O or missing 3 on CH_3 **Examiner's Comments** Most candidates were able to correctly recognise the correct direction for substitution, with over half gaining all 3 marks. Marks were most often lost for giving multiple substitution products despite being asked for the monosubstituted products. Many unnecessarily drew the same structures but with differentorientations i.e. substituting on carbon-3 of a ring is the same as substituting on carbon-5. **Misconception** Ensure students understand the term 'monosubstituted' and practise naming compounds to give the lowest possible numbering. This will also help them to recognise the equivalent structures.
		ii	 Correct organic product ✓ Correct balanced equation ✓	2	**ALLOW** any trichlorophenyl amine structure **ALLOW** $C_6H_2Cl_3NH_2$ **OR** $C_6H_4Cl_3N$ (allow elements in any order) for correct organic product **IGNORE** incorrect structural or molecular formula **IF** correct structure is drawn **ALLOW** ammonium salt of trichloro product $C_6H_2NH_3Cl_4$ **ALLOW** multiples for balanced equation **ALLOW** 1 mark for use of Br_2 with a correctly balanced equation **Examiner's Comments** The majority of candidates were able to give a suitable tri-substituted product, with many showing the structure although not asked for in the question. Many were also able to give a correct balancedequation too. Some were unsure how phenylamine would react showing the reaction with the aminegroup or only giving a monosubstituted product. Some didn't form HC*l* as another product, reacting

					phenyl amine with 1.5 Cl_2 instead. Others gave hydrogen as the product.
		iii	(In phenylamine) a (lone) pair of electrons on N is (partially) delocalised / donated into the π-system / ring ✓ Electron density increases/is higher (than benzene) ✓ **ORA** (phenylamine is) **more** susceptible to electrophilic attack **OR** (phenylamine) attracts/accepts electrophile/Cl_2 **more** **OR** (phenylamine) polarises electrophile/Cl_2 **more** ✓ **ORA**	3	Must be clear that electrons come from N not just NH_2 **ALLOW** the electron pair (in the p-orbitals) on N atom becomes part of the π-system / ring **ALLOW** diagram to show movement of lone pair into ring from N **ALLOW** lone pair of electrons on N is (partially) drawn / attracted / pulled into π-system / ring **ALLOW** lone pair on N (i.e. no reference to electrons) **ALLOW** π-bond instead of π-system / ring **DO NOT ALLOW** (two) lone pair**s** are delocalised/donated into the π-system / ring **Responses must be comparative for 2nd and 3rd marking point.** **IGNORE** activating **IGNORE** charge density **IGNORE** electronegativity **IGNORE** phenylamines react more readily with electrophiles/Cl_2 (*given in question*) **ALLOW** Cl^+ for electrophile **IGNORE** Cl for electrophile **ALLOW** Benzene can't polarise electrophile/Cl_2 but phenylamine can (polarise electrophile/Cl_2) **<u>Examiner's Comments</u>** Similar questions have been seen previously and many candidates were able to give clear and concise responses. The first marking point was the most frequently lost as although many described $-NH_2$ aselectron donating, they were not able to fully explain its role. Some understood that a lone pair wasdonated into the π-ring but did not specify that the lone pair was on the nitrogen. Other marks were lostby not making comparison to benzene, e.g. high electron density, polarises Cl_2. Some repeated theinformation from the question

					regarding phenylamine being more reactive with electrophiles but notexplaining why. Lower attaining candidates often described the structure of the benzene ring or referredto phenylamine being more electronegative.
			Total	**8**	
7			**A**	1	**ALLOW** HC*l* **Examiner's Comments** The vast majority of candidates gave the correct option A, HC*l*. The most common incorrect response was B i.e. H_2O.
			Total	**1**	
8		i	iron(III) oxide ✓	1	**IGNORE** iron(3) oxide, iron(III) dioxide, etc i.e. **MUST** be systematic **ALLOW** no brackets **Examiner's Comments** This question required candidates to work out a systematic name from a formula. Transition elements can have different oxidation numbers in their compounds and the systematic name needs to contain a Roman numeral. Approximately half the candidates were able to write the correct name as iron(III) oxide. An array of incorrect names were seen, commonly iron(II) oxide, presumably from the number of iron atoms in Fe_2O_3. **Misconception** A systematic name may contain the oxidation number, not the number of atoms in the formula. So Fe_2O_3 is iron(III) oxide and **not** iron(II) oxide.
		ii	$Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$ ✓	1	**ALLOW** multiples e.g. **2** Fe_2O_3 + **6** CO → **4** Fe + **6** CO_2 **ALLOW** 1 Fe_2O_3 ….. but **NOT** 0 Fe_2O_3 ….. **Examiner's Comments**

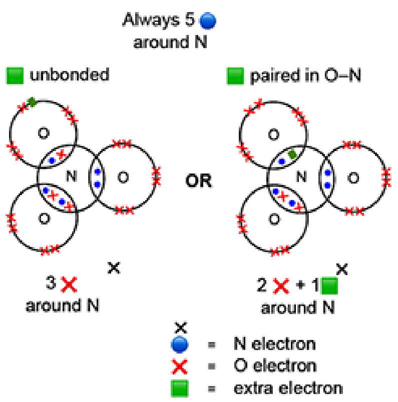
					Most candidates were able to balance this straightforward equation.
			Total	**2**	
9			$2\ Ba + O_2 \rightarrow 2\ BaO$ ✓ $BaO + H_2O \rightarrow Ba(OH)_2$ ✓ Neutralisation **OR** acid-base ✓	3	**ALLOW** multiples **IGNORE** state symbols, even if incorrect **ALLOW** $Ba + H_2O \rightarrow BaO + H_2$ (reaction with steam) **ALLOW** other correct equations e.g. with less reactive metal oxide **<u>Examiner's Comments</u>** Some candidates coped well with this question which was based on the AS part of the specification and gained all three marks. Common errors were for unbalanced equations in reaction 1 or adding H_2 to the product of reaction 2. Reaction 3 was often, incorrectly, considered as: redox, halogenation, nucleophilic substitution or a precipitation reaction **Assessment for learning** **OCR support** We have produced a topic exploration pack to assist with learning about the reaction of group 2 elements and their compounds: [Teach Cambridge (ocr.org.uk)]
			Total	**3**	
10	a		**Level 3 (5-6 marks)** Calculates **CORRECT** enthalpy change **AND** states **multiple** assumptions **AND** improvements *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Calculates **CORRECT** enthalpy change	1	**Indicative Scientific Points** **<u>Energy change from $mc\Delta T$</u>** Energy in J **OR** kJ $q = 100.0 \times 4.18 \times 18.6 = 7774.8$(J) **OR** 7.7748 (kJ) **<u>ΔH in kJ mol^{-1}</u>** $n(Cu(NO_3)_2) = 0.05$ (mol) $\Delta H = -q/n = 7.7748/0.05 = -155$ kJ mol^{-1} (3 SF) **ALLOW** -156 kJ mol^{-1} (use of 7.775 kJ) **ALLOW** answer in J mol^{-1} if units are

			OR Correctly calculates the moles **AND** attempts the calculation of q **AND** states **multiple** assumptions **OR** improvements. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Attempts any part of the calculation **AND** states **an** assumption **OR an** improvement. **OR** Correctly calculates the moles **AND** attempts calculation of q **OR** States **multiple** assumptions **OR** improvements *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.*		given **ALLOW** a single slip/rounding errors **<u>Assumptions and Improvements</u> (NOT INCLUSIVE)** ***Assumptions*** • density of solution is 1 g cm^{-3}/same as water • *c* of solution is same as water • ignore the mass and *c* of zinc • no heat escapes the system/lost to surroundings • mass of solution remains constant • no water lost/evaporated • reaction goes to completion • reaction completed under standard conditions • measurements recorded are accurate ***Improvements*** • polystyrene cup /thermos flask • use a lid • more precise thermometer • more precise balance • measure mass of solution • use burette to measure volume • use a cooling curve • use standard conditions Aspects of the communication statement might typically have been met when calculations have been completed in a logical order, and for L3 or L2 (where level awarded for calculation only) the use of the correct sign with the final answer given to 3 or 4 significant figures. **<u>Examiner's Comments</u>** The calculation of enthalpy change was generally well-answered and the majority of candidates were able to recall the equation $q = mc\Delta T$. Many candidates forgot the minus sign or gave a positive sign for final enthalpy change. Errors in calculation were most commonly for using an incorrect mass, usually by finding the mass of copper(II) nitrate (from moles and M_r). Some also used the wrong value for the heat capacity, selecting the value for R from the data sheet instead. Many gave the final answer to an

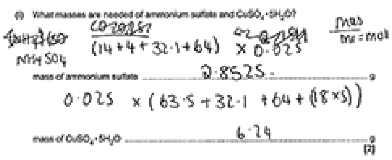
					inappropriate six significant figures. Candidates often found it challenging to give appropriate assumptions and improvements, limiting the level achieved to Level 2. However, many candidates did correctly give the assumptions that the specific heat capacity and density of the solution was the same as water. This is usually stated for the candidates with these types of questions. The most common improvements suggested were use of a polystyrene cup, adding a lid or using a thermometer with a higher resolution. Quite a few candidates suggested using a larger volume of solution which would indeed reduce the % uncertainty in the volume measurement. However, it would lead to a smaller temperature change, increasing the % uncertainty in the temperature measurement. Some confused the question with a calculation of enthalpy change of combustion and gave improvements accordingly, e.g. ‘use a copper or bomb calorimeter’, ‘draft shields’, ‘heat for longer’, ‘position of flame and supplies of oxygen’. Exemplar 2  0.5 × 100/1000 = 0.05 mol Q = mcΔT ∴ Q = 100 × 4.18 × (38.1 − 19.5) = 7774.8 ~~kJ~~ = 7.77 kJ 7.77 ÷ 0.05 = 155.5 kJ mol⁻¹ ∴ reaction is exo ∴ ΔrH = −155.5 kJ mol⁻¹ I assumed that the specific heat capacity of the solution is the same as the water. I assumed that no heat was lost to surroundings. I assumed that the mass of solution will same as it is ~~100cm³~~ 100g. I assumed the density of solution is same as water so 100 cm³ equals to 100g. Improvements can be do the experiment under standard conditions. Can also improve by using a larger mass of reactants ~~and~~ and also use a more accurate thermometer that can record to 2 decimal places. I can also improve by putting the beaker in another beaker with water to reduce heat loss to surroundings. This response achieved Level 3 - 6 marks. There is a correct calculation for ΔH, the final value has a correct negative sign and is given to 4 significant figures. Lots of valid assumptions and improvements are given.
	b		Half the energy/q **OR** volume/mass of solution **AND** half the moles ✓	2	**ALLOW** response that links the same proportionality/ratio of energy/volume/mass of solution to number of moles **ALLOW** same amount of energy

			Temperature change would be same✓		(released) per mole **ALLOW both marks** if seen by a calculation i.e. q = 50.0 x 4.18 x 18.6 = 3887.4(J) **OR** 3.8874(kJ) $n(Cu(NO_3)_2)$= 0.025 (mol) ΔH = (–) q/n = 3.8874/0.025 = (–)155 kJ mol^{-1}✓ Use of same temperature✓ May need to check answer in 3b to compare **IGNORE** Sign **<u>Examiner's Comments</u>** There was a lot of misunderstanding associated with this question, with many candidates failing to score any marks. Many said that nothing would change as the concentration was still the same or because the same bonds were being broken and formed. Under a quarter of students scored 1 mark, usually for making the link between the drop in volume to a change in the q and n values. A few did state that the temperature didn't change. Only a small proportion scored both marks, usually by showing by calculation that the temperature change was the same, moles was half and energy was half. Some did believe that the temperature changed, either that it decreased as less reacted or increased as there was less volume to heat. A wide variety of alternative responses were given including: 'Enthalpy change the same regardless of mass used' 'Number of moles doesn't impact energy required as it is the same bonds breaking' 'Energy to break and form bonds will still be the same with any volume' 'Amount of energy required to make the new bond would be the same' 'Only concentration has an effect on bond enthalpy values not volume'

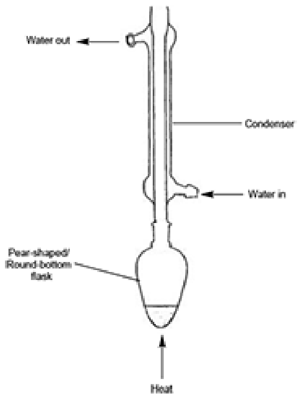
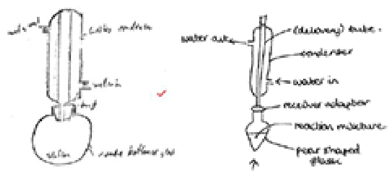
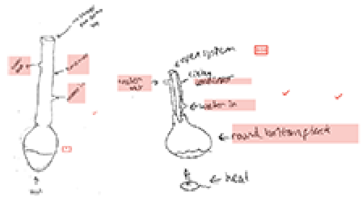
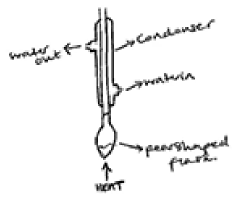
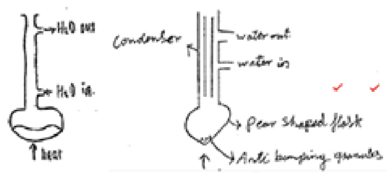
					‘Decrease in volume increases concentration’ ‘$Cu(NO_3)_2$ would still run out first so enthalpy change is the same’ ‘Zn is in excess so it doesn’t matter how much volume we use because Zn and $Cu(NO_3)_2$ still 1:1 ratio.’ ‘Mole ratio is still the same’ or ‘same molar ratio’ wasn’t enough.
			Total	**8**	
11	a		**H–O–N** 104.5° ✓ 2 bonded pairs/regions **AND** 2 lone pairs (around O) **AND** lone pairs repel more ✓ *Independent of bond angle* **O–N–O** 120° ✓ 3 bonded regions/pairs (around N) ✓ *Independent of bond angle*	4 (AO 1.2) (AO 2.1) (AO 1.2) (AO 2.1)	**Throughout,** • **IGNORE** names of shapes (even if wrong) • **IGNORE** ‘electrons repel’ • **DO NOT ALLOW** ‘atoms repel’ -- **ALLOW** 104–105º **ALLOW** lp for lone pair (of electrons) bp for bonding pair (of electrons) ‘bond’ for ‘bonded pair’ **IGNORE** electron density **ALLOW** 115–125º **ALLOW** 3 bonded areas / environments 3 regions / areas of electron density 3 bonded groups **ALLOW** 2 bonded pairs and 1 double bond **OR** 2 bonded pairs and 1 bonded region **<u>Examiner’s Comments</u>** This question required candidates to apply their knowledge and understanding of bond angles and electron pair repulsion in a novel context. The best candidates rose to this challenge, securing all four marks

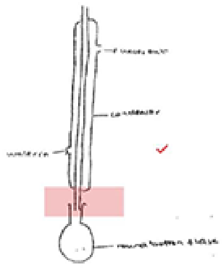
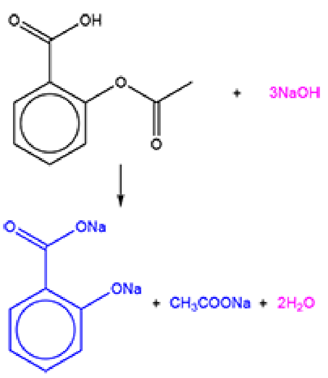
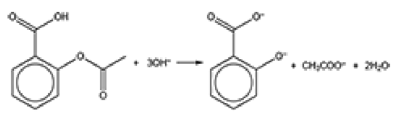
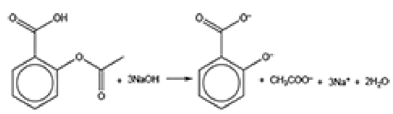
					for correct bond angles and explanations in terms of the numbers of bonded and lone pairs. The 104.5° and 120° were commonly seen and high scoring candidates provided excellent reasoning. The best explanation for 120° was in terms of three bonding regions and no lone pairs. Lower scoring responses often reasoned that bond angles are determined by lone pairs repelling the atoms, with the role of bonding pairs often being ignored.
	b	i	$Al_2O_3 + 6HNO_3 \rightarrow 2Al(NO_3)_3 + 3H_2O$ Any **THREE** species correct ✓ Correct balanced equation ✓ **DO NOT ALLOW** more than 4 species in equation	2 (AO 2.5) (AO 2.6)	**ALLOW** multiples **IGNORE** state symbols (even if wrong) **ALLOW ionic equation** $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$ Mark using same criteria **<u>Examiner's Comments</u>** Candidates were required to write a balanced equation for an acid–base reaction. As with Question 4 (b) (ii), candidates needed to write formulae from what should have been common ions, but the formulae for aluminium oxide and aluminium nitrate were often incorrect. In the equation, the reactants and products were sometimes unbalanced, or incorrectly balanced. A common error was H_2 instead of H_2O as the second product. The question was an excellent discriminator.
		ii		2 (AO 2.1) (AO 2.5)	**NOT REQUIRED** • Charge ('–') • Brackets • Circles • N and O symbols **IGNORE** inner shells **ALLOW rotated diagram** In **N=O bond, ALLOW** sequence **× × • •**

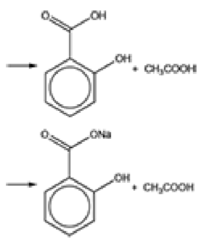
			1st mark: 8 Electrons around N as above 1 single covalent bond, 1 dative covalent bond 1 double bond **2nd mark:** 8 electrons around each O **AND** 6 O electrons around each O Only award 2nd mark if 1st mark awarded **NO ECFOR**		**ALLOW** non-bonding electrons unpaired **ALLOW** dot and cross labels swapped: i.e. • for O electrons and × for N electrons **<u>Examiner's Comments</u>** Candidates were expected to use the displayed formula of nitric acid to identify that the central N atom had one double bond, one covalent bond and one dative covalent bond. This information then gave the strategy for the dot and cross diagram. Although virtually all candidates attempted the dot and cross diagram, only about a quarter of candidates could be credited with a meaningful response. The key was to use nitrogen's 5 outer shell electrons and to combine these with 3 oxygen electrons or 2 oxygen electrons and the extra electron. Then the remaining oxygen electrons could be added, taking care that there were 6 around out O atom. Finally the extra electron would need to be placed in an octet gap. Many candidates showed just 4 nitrogen electrons and this approach resulted in no marks. Other common errors included 3 double bonds around the N atom, and a lone pair on the N atom. This dot and cross diagram discriminated between higher scoring candidates extremely well.
			Total	**8**	
12	a		Any correct formula for $\mathbf{X}_2\mathbf{Y}(\mathbf{Z}O_4)_2$ • $6H_2O$ ✓ with suitable elements for **X**, **Y** and **Z** using information in stem: • **X** can be K, Rb, Cs, Fr **ONLY** • **Y** can be Mg or a transition element in period 4: Ti → Ni • Z must be Cr **Example: $K_2Mg(CrO_4)_2$ • $6H_2O$**	1 (AO 3.2)	Suitable transition elements: Ti, V, Cr, Mn, Fe, Co, Ni • *Cu in in the Tutton's salt in Q4* • *Sc and Zn and not classified as transition elements* **<u>Examiner's Comments</u>** Question 4 assesses candidates' ability to apply their chemical knowledge and understanding from different parts of the specification in a novel context. Information is supplied throughout the question, and clues are sometimes

					presented to candidates. In part (a), candidates are introduced to Tutton's salts and are given an example of a Tutton's salt that forms the context of the whole question. A candidate needs to apply the information in the bullet points to predict the formula of a different Tutton's salt. This question discriminated extremely well across different abilities and highlighted that some candidates struggled to use supplied information. This was repeated in other parts of Question 4. Just over half the candidates gave a correct formula from the information. Some candidates did not choose one of the acceptable ions shown in the first and second bullet points, and many chose S rather than Cr, despite S being in the supplied Tutton's salt; a significant number omitted the $\bullet 6H_2O$.
	b	i	Mass $(NH_4)_2SO_4$ = 3.3025 g ✓ Mass $CuSO_4 \bullet 5H_2O$ = 6.24 g ✓	2 (AO 1.2 ×2)	**ALLOW** 3.3, 3.30. 3.303 **ALLOW** 6.2 **<u>Examiner's Comments</u>** This question required candidates to calculate the masses of two reactants that could be used to prepare a sample of the Tutton's salt. Candidates were supplied with the formula of hydrated copper(II) sulfate but not the formula of ammonium sulfate, so candidates needed to work out its formula from ions that candidates are expected to be able to recall from the specification. Just over half the candidates obtained both correct masses but many obtained just one correct mass, usually that of $CuSO_4 \bullet 6H_2O$. Exemplar 3  What masses are needed of ammonium sulfate and $CuSO_4 \bullet 5H_2O$? $(14+4+32.1+64) \times 0.025$ mass of ammonium sulfate .... 2.8525 .... g $0.025 \times (63.5+32.1+64+(18\times5))$ mass of $CuSO_4 \bullet 5H_2O$ .... 6.24 .... g [2]

					This exemplar shows a typical response with the incorrect formula of ammonium sulfate clear shown by the candidate, resulting in the incorrect mass of 2.8525 g. This incorrect formula and mass were seen in many responses and, from the initial crossings out, this candidate is clearly confused about how to tackle this simple mole calculation. The incorrect answer of 2.85 g was seen on almost as many scripts as the correct answer of 3.30 g. The moral is that candidates need to learn the formula and charges of the common ions encountered in chemistry. The comments here apply also to Question 6 (b) (i), where formulae need to be written using ions listed in the specification.
		ii	• Prevents water of crystallisation from being removed • Anhydrous salt would form • Prevents dehydration ✓	1 (AO 3.4)	**IGNORE** all the water would be removed *water is the solvent* **IGNORE** prevents decomposition **IGNORE** increases the size of crystals **<u>Examiner's Comments</u>** The majority of candidates did not answer this question correctly. Candidates were expected to refer back to the formula of the Tutton's salt, spot that there was water of crystallisation present, and that this would be lost if all the solvent was boiled off. Many responded vaguely in terms of decomposition or formation of larger crystals but a mark was only awarded if there was a definite link to the water contained within the crystals. **Assessment for learning** In the specification, Section 2.1.2a states the following: (a) the writing of formulae of ionic compounds from ionic charges, including: i. prediction of ionic charge from the position of an element in the periodic table

					ii. recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^{+u}. This section will be studied at the start of the 2 year course. Candidates need to be confident with using these common formulae. For success in chemistry, these ions must be learnt.
			Total	**4**	
13		i	 **Reaction apparatus (Labels NOT required)** flask **AND** upright condenser **AND** open system at top ✓ *(Could be labelled)* **Labels AND direction of water flow** Pear-shaped/round-bottom flask **AND** condenser **AND** water in at bottom and out at top ✓ Heat **NOT** required **DO NOT ALLOW** flask, conical flask, volumetric flask **DO NOT ALLOW** thermometer **DO NOT ALLOW** condensing tube as label	2 (AO 3.3 ×2)	For open system, **DO NOT ALLOW**  **For open system, ALLOW** label. e.g. ‘open at top’  **ALLOW** line across flask   **ALLOW small** gap between flask and condenser **BOD**, e.g.

					 **If in doubt, ask Team Leader** **<u>Examiner's Comments</u>** Most candidates drew a diagram that looked like a vertical condenser above a flask. The quality of the diagrams was not very good. Candidates then needed to label their diagram. Errors included a bung or thermometer inserted at the top of the condenser and water flowing the wrong way in the condenser. For labelling, candidates were expected to use scientific terminology. Responses such as 'condensation tube' and vague terms such as 'flask' were not credited. These labels were often omitted. A significant number drew a set up for distillation instead of reflux.
		ii	 Organic products ✓ ✓ ***2 marks*** 3NaOH AND $2H_2O$ ✓ ***1 mark*** NOTE: ALLOW O^-Na^+ for ONa throughout **SCROLL DOWN FOR PRODUCTS**	3 (AO 2.6 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** annotations of provided structure of aspirin at top left **ALLOW** equation with 3OH– **OR** 3NaOH giving anions for organic products, i.e.  **OR**  **ALLOW** 1 of the 2 organic products mark for BOTH structures as COOH and OH (or mixture) e.g

					 **<u>Examiner's Comments</u>** This question was the hardest part of Question 5 and about half the candidates were not given any marks. Some drew the sodium carboxylate salt of aspirin structure, leaving the ester link intact. A large number of candidates realised that the ester would be hydrolysed. Sometimes the sodium salts were often not shown and, even they were shown, the phenol group was often shown intact. The hardest mark was the formation of $2H_2O$ and a large number of candidates showed the more intuitive but incorrect '$3H_2O$' instead.
			Total	**5**	
14	a	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **if answer = 6.77 award 2 marks** -- $K_w = [H^+][OH^-]$ **OR** $K_w = [H^+]^2$ **OR** $[H^+] = \sqrt{K_w}$ ✓ $([H^+] = \sqrt{(2.92 \times 10^{-14})})$ pH = $-\log(1.71 \times 10^{-7}) = 6.77$ ✓	2 (AO 1.1 × 1) (AO 2.2 × 1)	**DO NOT ALLOW** use of A^- or X^- **<u>Examiner's Comments</u>** Most candidates were given the first mark from a correct or rearranged equation. Many candidates then answered this question correctly and were given both marks. Those who didn't, either used 1.00×10^{-7} as $[OH^-]$ when calculating $[H^+]=Kw/[OH^-]$ or calculated pH as -log(2.92×10^{-14}).
		ii	(In pure water), $[H^+]$ (always) equals $[OH^-]$	1 (AO 3.2 × 1)	**ALLOW** moles/number of H^+ is (always) equal to moles/number of OH^-. **DO NOT ALLOW** ratio $[H^+] : [OH^-]$ doesn't change **<u>Examiner's Comments</u>** This question proved difficult with only a few candidates able to state that in neutral water, $[H^+] = [OH^-]$. Many candidates said that as the pH is close to 7, water is therefore neutral.

<table>
<tr>
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<td>b</td>
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- **Equation**
$Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ ✓

CHECK THE ANSWER ON ANSWER LINE
if answer = 11.51 award 4 calculation marks

- **n($Sr(OH)_2$)**
$= \frac{0.145}{121.6} = 1.1924\ldots \times 10^{-3}$ ✓
- **[OH^-]**
$= 2 \times (1.1924 \times 10^{-3} \div 0.25) = 9.539\ldots \times 10^{-3}$ ✓
- **[H+]** = $K_w \div [OH^-]$
$= \frac{0.145}{121.6} = 3.061\ldots \times 10^{-12}$ ✓
- **pH** = $-\log(3.061\ldots \times 10^{-12}) = 11.51$ ✓

2 DP required
</td>
<td>5
(AO 2.6)
(AO 2.4 × 3)
(AO 1.2 × 1)</td>
<td>

IGNORE state symbols (even if wrong)
ALLOW multiples

ALLOW $Sr^{2+} + 2OH^-$ for $Sr(OH)_2$

ALLOW 3 SF up to the calculated value. Ignore RE after 3SF.

ALLOW ECF throughout but final answer must be pH>7

Final answer must be from calculated values.

Common errors for 3 calculation marks

11.98 *(Use of $K_w = 1 \times 10^{-14}$)*
11.21 *(no × 2)*
10.91 *(÷ by 2)*

Common error for 2 calculation marks

pH = 11.67 *(no × 2 and wrong K_w)*

Alternative method for:-
pH = pKw – pOH

- ***n*($Sr(OH)_2$)**
$= \frac{0.145}{121.6} = 1.1924\ldots \times 10^{-3}$
- **[OH^-]**
$= 2 \times (1.1924 \times 10^{-3} \div 0.25) = 9.539\ldots \times 10^{-3}$
- ***pH*** *= pKw - pOH*
= (-log 2.92 x 10^{-14}) - (-log 9.539..x 10^{-3})
</td>
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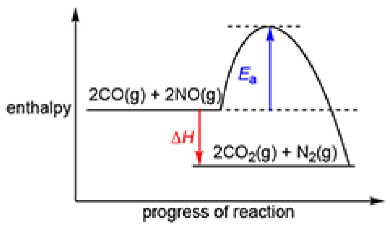
</table>

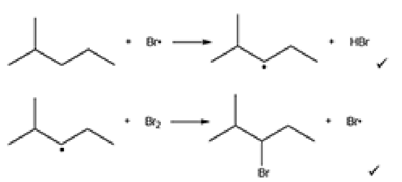
					• ***pH** = 13.53(46) - 2.02(05)* **= 11.51** **<u>Examiner's Comments</u>** Most candidates wrote the correct equation. Common errors were using Sr^{2+} as reactant, not balancing the H_2O and not having the H_2 as second product. Most candidates calculated the moles of $Sr(OH)_2$ correctly but fewer recognised that $[OH^-]$ = twice the $[Sr(OH)_2]$. As a result, most candidates scored 3 calculation marks. A few candidates chose the incorrect K_w value.
	c	i	$SrCO_3 + 2HNO_3 \rightarrow Sr(NO_3)_2 + H_2O + CO_2$ ✓	1 (AO 2.6)	**IGNORE** state symbols **DO NOT ALLOW** H_2CO_3 for $H_2O + CO_2$ (question states that a gas was produced) **ALLOW** multiples **<u>Examiner's Comments</u>** This was often answered correctly but some candidates gave the incorrect formulae for $Sr(NO_3)_2$ and either no other product or H_2 gas.
		ii	M_r of $SrCO_3$ is different to M_r $CaCO_3$ / moles $SrCO_3$ are different to moles $CaCO_3$ ✓ M_r of $SrCO_3$ > M_r $CaCO_3$ / moles $SrCO_3$ < moles $CaCO_3$ **AND** **More** moles/volume gas (from $CaCO_3$)✓	2 (AO 3.1 × 1) (AO 3.2 × 1)	**ALLOW** ORA **ALLOW** $n(SrCO_3) = (1.00 \div 147.6) = 6.78 \times 10^{-3}$ (mol) **AND** $n(CaCO_3) = (1.00 \div 100.1) = 9.99 \times 10^{-3}$ (mol) For the 2nd mark, we are assessing the idea of the greater moles of carbonate produces more gas. Subsumes first mark **ALLOW** $n(SrCO_3) = (1.00 \div 147.6) = 6.78 \times 10^{-3}$ (mol) **AND** $n(CaCO_3) = (1.00 \div 100.1) = 9.99 \times 10^{-3}$ (mol) **AND** Calculated values (CO_2) 163 cm^3 **AND** 240 cm^3 **<u>Examiner's Comments</u>**

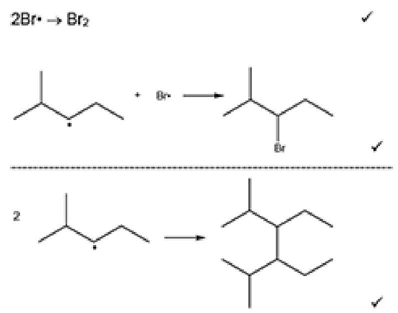
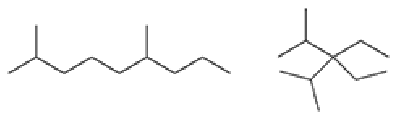
					Only a few candidates used the mass value given in the question to link the number of moles of the group 2 metal carbonate and the number of moles, and hence volume, of gas produced. **Misconception** Many candidates answered this question in terms of the relative reactivity, or solubility of Ca and Sr and then continuing by explaining their respective ionisation energies.
			Total	**11**	
15			**3**V^{3+} + $Cr_2O_7{}^{2-}$ + **2**H^+ → **3** VO_2^+ + **2**Cr^{3+} + H_2O **ALL** reactant and product species correct ✓ Correct balancing (of correct equation) **AND** cancelling of species ✓	2 (AO 2.5) (AO 2.6)	**IGNORE** Balancing and electrons for first mark **DO NOT ALLOW** electrons in final answer **<u>Examiner's Comments</u>** Very few candidates were able to produce the balanced overall equation; a few had the correct reactants and products but not balanced. Candidates are advised to look for the information contained within the question. The formulas were given, and it was stated that the solution was acidified, leaving only water to be identified. Some candidates approached this through two half equations whereas others used oxidation numbers to balance their equations.
			Total	**2**	
16			**C**	1 (AO 2.6)	**<u>Examiner's Comments</u>** Most candidates answered this question correctly with C.
			Total	**1**	
17			**Correct structural isomers of C_3H_8O** *1 mark*		**ANNOTATE WITH TICKS AND CROSSES** **Throughout,** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

			$CH_3CH_2CH_2OH$ **AND** $CH_3CHOHCH_3$ ✓ **Reaction conditions** *1 mark* Distillation for aldehyde **AND** reflux for carboxylic acid **OR** ketone ✓ **Functional group of organic product** *2 marks* $CH_3CH_2CH_2OH$ → aldehyde **OR** → carboxylic acid ✓ $CH_3CHOHCH_3$ → ketone ✓ **One correct equation** *1 mark* $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ **OR** $CH_3CHOHCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$ **OR** $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓		**IF functional group is NOT given,** **ALLOW** propanal / RCHO **ALLOW** propanoic acid / RCOOH **ALLOW**propanone / ..... RCOR **IGNORE** small slips in formulae (assessed in equation) __**Examiner's Comments**__ There were some excellent responses to this question which discriminated extremely well. Unfortunately, there were a significant number of incorrect responses and some less successful candidates had clearly struggled to recall and apply this important material. The identification of the isomers was usually correct, as was the identification of the oxidation products from the primary and secondary alcohols, and the conditions required to produce the organic products. The equation proved to be the hardest requirement with the H_2O by-product often being omitted or H_2 shown instead. A general point applies to organic structures. Some candidates did not show the structures of the isomers and attempted this question using the molecular formula of C_3H_8O supplied in the question for both alcohol isomers and no structural formulae. It was then impossible to know which isomer was being reacted and this could cost the candidate a significant number of marks. It is essential in organic chemistry to use unambiguous formulae which can be any combination of skeletal, structural or displayed. Unless a question specifies that a molecular formula is required, candidates should assume that an unambiguous formula is required.
			Total	5	

18		i	$CuO + 2HCl \rightarrow CuCl_2 + H_2O$ ✓	1 (AO2.6)	**ALLOW** multiples **IGNORE** state symbols **IGNORE** charges, even if wrong **<u>Examiner's Comments</u>** This question required candidates to recognise the reaction as being 'acid–base' and to interpret a formula from a name containing a Roman numeral. Candidates identifying the formula of copper(II) oxide as CuO were normally able to complete the equation. A reasonably large number identified the copper compounds as CuO_2 and CuCl. Overall, most candidates produced a correct equation.
		ii	$(NH_4)_2CO_3 + 2HNO_3 \rightarrow 2NH_4NO_3 + CO_2 + H_2O$ Any 4 formulae correct ✓ All 5 formulae correct and balanced ✓	2 (AO2.6 ×2)	**ALLOW** multiples **IGNORE** state symbols **IGNORE** charges, even if wrong **ALLOW** H_2CO_3 for $CO_2 + H_2O$ *Counts as 2 formulae for marking criteria* **<u>Examiner's Comments</u>** This item was much more demanding than the equation in 22(b)(i) and was often answered incorrectly. Most were unable to work out the formula of the two ammonium compounds, with NH_3 often shown instead of NH_4. A mark was available for 4 of the 5 formulae being correct but comparatively few were able to construct the correct balanced equation. Candidates are expected to know the formula and charge of ammonium and carbonate ions and the common acids (sulfuric, hydrochloric and nitric) and these are clearly listed in the specification.
			Total	**3**	
19		i	$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ Correct species ✓ Balanced ✓	2 (AO2.6 ×2)	**ALLOW** multiples **IGNORE** state symbols For heptane formula, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW 1 mark** for balanced combustion equation for a different alkane (**ECF**) e.g. $C_6H1_4 + 9½O_2 \rightarrow 6CO_2 + 7H_2O$ **<u>Examiner's Comments</u>**

					Most candidates were able to construct a balanced equation for the combustion of heptane. Most were aware that CO_2 and H_2O would be the products although some generated CO, C_6H_{12} or unusual compounds such as $C_7H_{14}O$. The hardest part was the formula of heptane itself with use of hexane instead being a common error; candidates who made this error were given 1 mark, provided that their equation was balanced.
		ii	 **Reactants, products and Δ*H*** **2CO + 2NO** on LHS **AND** **$2CO_2$ + N_2** on RHS **AND** Δ*H* labelled with products **below** reactants **AND** **Arrow downwards** ✓ ***E_a* (independent of Δ*H*)** curve with arrow from reactants to top of curve **AND** *E_a* labelled ✓ **IF** endothermic diagram shown, **ALLOW ECF** for E_a using MS criteria	2 (AO2.1) (AO1.2)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols Δ*H* **DO NOT ALLOW –Δ*H*** **DO NOT ALLOW** double headed arrow on Δ*H* **ALLOW** Δ*H* arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line. **ALLOW** –746 for Δ*H* ***E_a*** **ALLOW** AE **OR** A_E **ALLOW 2** arrowheads at **each** end of E_a line **OR** no arrowhead **BUT DO NOT ALLOW** arrowhead down E_a line must reach maximum (or near to maximum) on curve **<u>Examiner's Comments</u>** Most candidates obtained 1 or 2 of the available marks, the commonest errors being use of a doubleheaded arrow for Δ*H* or a –Δ*H* label. Some candidates showed endothermic profiles and these could create issues with positioning of the Δ*H* and E_a arrows. Generally, positioning of Δ*H* and E_a

					arrows was imprecise and candidates are advised to start and finish the positions of their arrows accurately. The mark scheme did allow for some leeway but positioning of arrows could generally be improved.
		iii	Catalyst lowers activation energy **OR** Catalyst increases rate without itself changing ✓ Reaction proceeds via a different route/pathway **OR** More molecules/particles exceed activation energy ✓	2 (AO1.2 ×2)	**ALLOW** 2nd labelled curve on profile diagram in **23(a)(ii)** with lower activation energy/E_c with catalyst **ALLOW** E_c needs less energy to start reaction **ALLOW** E_c curve is lower than E_a curve **IGNORE** 'shorter route' for alternative route **IGNORE** more successful collisions **<u>Examiner's Comments</u>** Almost all candidates knew that a catalyst lowered activation energy and most were aware that an alternative pathway was made possible by a catalyst.
			Total	**6**	
20			**C**	1 (AO 2.1)	**<u>Examiner's Comments</u>** Most candidate chose the correct response of C. From the annotations on the scripts, most candidates identified the largest jump between the 3rd and 4th ionisation energies. Option D proved to be the main distractor. Having identified the correct large jump, a significant number of candidates chose the group at the end of the jump (Group 4) rather than the group at the start of the jump (Group 3). This suggests a misconception.
			Total	**1**	
21	i		**Initiation** $Br_2 \rightarrow 2Br•$ **AND** ultraviolet / UV ✓ **Propagation** 	6 (AO1.1) (AO2.5) (AO2.5) (AO2.5) (AO3.1)	**DOT REQUIRED** throughout **IGNORE** temperature and pressure **ALLOW ECF** for use of Cl• (from Cl2) in subsequent propagation and termination steps **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** 1 mark for propagation for 2 'correct' equations but with dot omitted or in wrong position

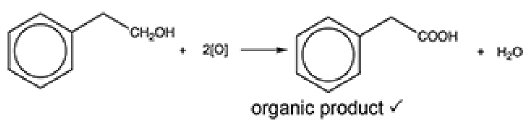
			Termination 		**DO NOT ALLOW ECF** from incorrect radical intermediate for termination steps __**Examiner's Comments**__ Many candidates tackled this question confidently, especially when using skeletal formula following the format of the structure given in the question. Over half the candidates scored 5 or 6 marks. Only the highest attaining candidates were able to provide all three correct termination steps. Many lost a mark for the combination of the two alkyl radicals, typically either by simply joining the ends of the chains or by missing the connecting C-C bond.  Those that attempted to use structural formula often lost marks due to missing Hs. Other common errors included the incorrect positioning of the radical dot, most typically on the terminal carbon, addition of Br in the first propagation step or use of molecular formula. Lower attaining candidates were often able to score a mark for the initiation step and the termination step involving two Br radicals. However, for some this was not a well-known mechanism, with attempts to break up the chain or form hydrogen radicals or charged species. Errors were also seen with correct balancing of equations such as truncated C chains or extra Br atoms added.
		ii	C_6Br_{14} ✓ Correct balanced equation $C_6H_{14} + 14\ Br_2 \rightarrow C_6Br_{14} + 14\ HBr$ ✓	2 (AO2.6 ×2)	**ALLOW** 1 mark for correct balanced equation using any combination of skeletal **OR** structural **OR** displayed formula __**Examiner's Comments**__ Most responses gained at least 1 mark for this question giving the correct molecular

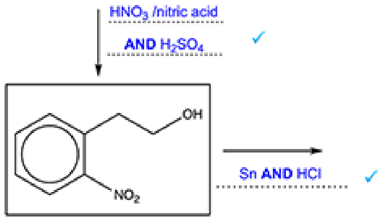
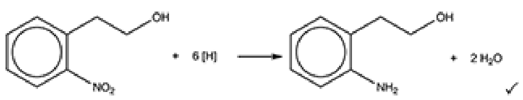
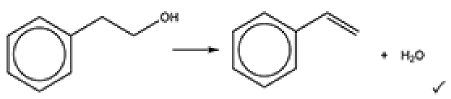
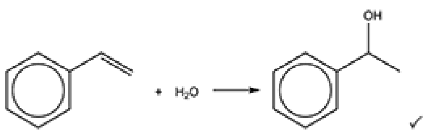
					formula of C_6Br_{14}. However many hadn't assimilated that when a hydrogen atom is substituted in an alkane it requires one mole of a halogen and produces one mole of the hydrogen halide. So many gave this incorrect equation instead: $C_6H_{14} + 7Br_2 \rightarrow C_6Br_{14} + 7H_2$. Some lost marks for C_5H_{14} or for use of structural formulae.
		iii	$n(\mathbf{B}) = \frac{72.0}{40000}$ **OR** $\frac{0.072}{40}$ **OR** $1.8(0) \times 10^{-3}$ (mol) ✓ $M(\mathbf{B}) = \frac{0.8649}{1.8(0) \times 10^{-3}} = 480.5$ ✓ Molecular formula = $C_6H_9Br_5$ ✓	3 (AO2.2 ×2) (AO3.2)	**ALLOW 2SF** up to calculator value **ALLOW ECF** from incorrect *n*(**B**) **ALLOW ECF** from incorrect *M*(**B**) from *n*(**B**) --- **COMMON ERROR** $n(\mathbf{B}) = \frac{72.0}{24000} = 3 \times 10^{-3}$ (mol) ✗ $M(\mathbf{B}) = \frac{0.8649}{3 \times 10^{-3}} = 288.3$ …………….✓ Molecular formula = $C_6H_{12}Br_2$ **OR** $C_6H_{11}Br_3$ ✓ **ALLOW ECF** for viable molecular formula with C_6 but must be derived from a calculated value for *M*(**B**) **<u>Examiner's Comments</u>** Overall, this question was well answered with over half of candidates gaining all 3 marks. The use of a different molar volume confused some candidates. Some attempted to use PV=nRT or different combinations of the figures given with varying degrees of success. Lower attaining candidates typically struggled with unit conversions and were unable to make use of the units to help them work out the methodology to use.
			Total	**11**	
22			$C_6H_{11}OH$ ✓ Correct balanced equation $C_6H_{11}OH + 8\frac{1}{2} O_2 \rightarrow 6 CO_2 + 6 H_2O$ ✓	2 (AO2.6 ×2)	For $C_6H_{11}OH$, **ALLOW** $C_6H_{12}O$ **OR** any combination of skeletal **OR** structural **OR** displayed formula **ALLOW** multiples **IGNORE** state symbols **ALLOW** multiple OH groups in structure for both marks e.g.

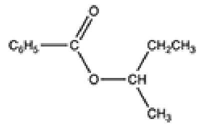
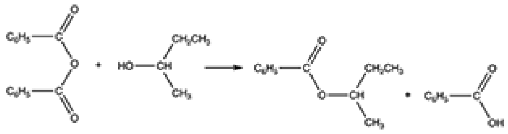
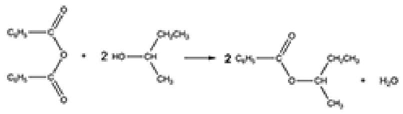
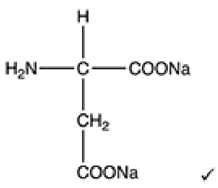
					$C_6H_{12}O_2$ ✓ $C_6H_{12}O_2 + 8\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ✓ **Examiner's Comments** Approximately half the candidates gained both marks here but just over a third gained no credit. A very common error was $C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$ missing the need for an alcohol group. Another common error was balancing with $9O_2$ i.e. not deducting O from alcohol from their count of O atoms. Some struggled to determine the correct number of Hs when a single C=C bond is introduced so gave $C_6H_{12}OH$ or $C_6H_{13}OH$ instead. Lower attaining candidates did not understand what happens during complete combustion. For example, they used [O] instead of molecular oxygen or didn't have CO_2 and water as the products. Some used structural formula which made it easier to get the correct formula of the reactant but often made it trickier to balance the equation.
			Total	**2**	
23			**B**	1 (AO2.2)	**Examiner's Comments** This was a demanding question. Candidates needed to calculate the moles of oxygen and then determine the ratio of alkane to oxygen to find the correct response. The majority of successful candidates clearly showed their working to help them to arrive at the correct answer. The most common incorrect answer was C.
			Total	**1**	
24	a	i	**Equation** $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$ All formulae and balancing correct ✓ **Observation** Effervescence/fizzing/bubbles **OR** Ca/solid disappears/dissolves **OR** Forms a white ppt/solid ✓	2 (AO 2.6) (AO 1.2)	**ALLOW** correct multiples including fractions **IGNORE** state symbols, even if wrong **IGNORE** temperature change, pH change or gas formed i.e. must be an observable change. **IGNORE** turns cloudy **DO NOT ALLOW** Colour change **Examiner's Comments**

					Most candidates scored the mark for the correct observation. A few said what would happen rather than what they would see, e.g. gas is formed, pH would increase, mass lost or even reference to the 'squeaky pop' test. Many struggled to give the correct balanced equation with either CaO being given as a product or incorrect balancing. Many did not have a gas produced but then had bubbling as an observation. **OCR support** OCR has some resources to help support the understanding of balancing symbol equations such as this delivery guide for Atoms and equations.
		ii	More vigorous effervescence/fizzing/bubbling **OR** Ba/solid disappears/dissolves faster **OR** White ppt formed less rapidly ✓	1 (AO1.2)	**ORA** if clearly references Ca **ALLOW** AW such as stronger/ rapid/ quicker/ more quickly/ more violent **ALLOW** less or no ppt (as barium hydroxide is more soluble) **Note**: Must reference observation not just reaction e.g. more vigorous reaction. **IGNORE** finishes first **IGNORE** more bubbles (need idea of rate) **IGNORE** exothermic **<u>Examiner's Comments</u>** Responses not about observations were very common, e.g. more vigorous reaction, Ba is more reactive. Some described Ba as being less reactive. Many responses did not include the idea of rate (for example, 'more bubbles') or were not comparative (for example, 'vigorous bubbling').
	b	i	$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ Balanced equation ✓ State symbols ✓	2 (AO 2.5 x 2)	**ALLOW** ionic equation $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ **M2 dependent on M1** **IGNORE** NaCl balanced on both sides **<u>Examiner's Comments</u>**

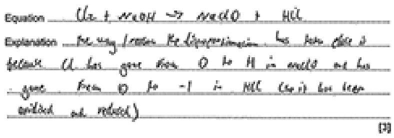
					Less than half the candidates gained credit for this challenging question. There was lots of information to process. Many struggled to give the correct formula for the products, e.g. $NaNO_3$, Ba_2SO_4, or had issues with balancing. Some tried to involve the NaCl in the reaction, either recognising that it didn't react (acceptable on the mark scheme) or forming barium chloride or even Cl_2. Lots of candidates lost the mark for state symbols as they left $Ba(NO_3)_2$ as (s), not recognising that in step 1 the mixture was dissolved in water so should now be (aq).
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 26.6 % award 4 marks** -- $n(BaSO_4)$ = $\frac{3.28}{233.4}$ **OR** 0.014053… (mol) ✓ mass $Ba(NO_3)_2$ = 0.014053… × 261.3 **OR** 3.672.......(g) ✓ mass NaC*l* = 5.00 – 3.672.. **OR** 1.3279… (g) ✓ % NaC*l* = $\frac{1.3279 \times 100}{5.00}$ = 26.6(%) **3 SF** ✓	4 (AO 3.1 ×3) (AO 3.2)	**ALLOW ECF** from incorrect equation in 2(b)(i) and throughout **ALLOW 3SF** up to calculated value throughout **IGNORE** rounding errors past **3SF** *Calculator:* 0.01405312768 *Calculator:* 3.672082262 *Calculator:* 1.327917738 **ALLOW ECF** for use of calculated mass NaCl e.g. 0.014053…x 58.5 = 0.8221…. to give final % 16.4 to 3SF -- **Alternative approach for last 2 marks** % $Ba(NO_3)_2$ = $\frac{3.672 \times 100}{5.00}$ = 73.44 … ✓ % NaC*l* = 100 – 73.44 = 26.6 % ✓ **<u>Examiner's Comments</u>** This was a tricky calculation, made more challenging if candidates hadn't been able to successfully complete (i). Many were able to calculate the moles of $BaSO_4$ but often rounded their answer to only 2 significant figures at this stage i.e. 0.014. Many assumed a direct ratio between $BaSO_4$ and NaCl so mass was found by multiplying moles by 58.5 (molar mass for NaCl) - if this was done then credit was given for ECF for the final marking point. **OCR support**

					The M1 section of the Mathematical Skills handbook contains useful information on handling data, including M1.1 use of significant figures.
		iii	Silver chloride/AgC*l* would be produced (as a precipitate) ✓ (Mass of NaC*l*) can be calculated from the mass/moles of AgC*l* ✓	2 (AO 3.4 × 2)	**ALLOW** Chlor**ide** reacts to give (white) ppt **IGNORE** incorrect formula of silver chloride **ALLOW** equation showing formation of AgCl(s) **ALLOW** Weigh AgC*l* and use to calculate %/mass/moles **<u>Examiner's Comments</u>** Another tricky question with less than half gaining credit. Many were able to recognise the addition of silver nitrate as the test for halide ions but did not realise that it could be used quantitatively. Many didn't read the question carefully and assumed Na_2SO_4 was still present, giving a mixture of two precipitates. Some, despite recognising the formation of AgCl, could not then see how to calculate the mass of NaCl i.e. "you won't have formation of $BaSO_4$". Some suggested that barium nitrate would also form a precipitate, perhaps confused by the (s) state symbol in the question.
			Total	**11**	
25	a		 Correct balanced equation ✓	2 (AO2.5) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_6H_5 for phenyl group **<u>Examiner's Comments</u>** Most candidates were able to score at least 1 mark for this question. Common errors included candidates producing two water molecules or failing to balance [O]. A significant proportion of candidates did not score any marks, frequently due to the organic product having too many carbon atoms in it.
	b	i		2 (AO1.2×2)	

					**IGNORE** references to concentration **IGNORE** 'dilute' for HC/ **IGNORE** H_2 **IGNORE** NaOH if seen as a reagent to convert nitro group into amine e.g 'Sn/(concentrated) HCl then NaOH' scores the mark
		ii		1 (AO2.6)	<u>**Examiner's Comments**</u> Candidates were familiar with the reagents required in these two reactions. The most able candidates were able to identify the use of 6[H] as the reducing agent and the production of 2 water molecules. Incorrect responses commonly included the use of HCl and $NaBH_4$ as a reactant.
	c		**Stage 1** *Reagents*: H_2SO_4 ✓  **Stage 2** *Reagents*: Steam/H_2O(g) **AND** acid/H^+ (catalyst) ✓ 	4 (AO3.1) (AO2.6) (AO3.1) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ **OR** HCl **OR** H_3PO_4 **DO NOT ALLOW** other named acids **IGNORE** concentration/pressure **IGNORE** water/steam For steam, **ALLOW** H_2O with temperature ≥100°C **ALLOW** use of H_3PO_4/H_2SO_4 as catalyst **DO NOT ALLOW** HCl **IGNORE** pressure <u>**Examiner's Comments**</u> This question proved challenging with only the most able being given full marks. The reagents and conditions were not well known and candidates did not include water in their equations to make sure they were balanced.
	d		Structure of ester product ✓	2 (AO3.1) (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

			 Correct balanced equation ✓ 		**ALLOW**  **<u>Examiner's Comments</u>** Most candidates did not secure a mark in this question. Many candidates used butan-1-ol in their equations or used benzoic acid rather than benzoic anhydride as the reactant. The most able candidates suggested that the benzoic acid product would then further react with butan-2-ol to produce a second ester molecule and water. This was an acceptable alternative response.
			Total	**11**	
26			$C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓ $2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓ H_2O **AND** CO_2 ✓ 	4 (AO2.6×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** state symbols and use of equilibrium sign **ALLOW** KC_2H_5COO **DO NOT ALLOW** a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but **IGNORE** for next equations. For salts, **ALLOW** $C_2H_5COO^-K^+$ **OR** $C_2H_5COO^- + K^+$ **DO NOT ALLOW** –COO–K (covalent bond) the 1st time seen but **IGNORE** for next equations. **FOR** $CO_2 + H_2O$ **ALLOW** H_2CO_3 **<u>Examiner's Comments</u>**

			Correct formula of salt:		This question proved challenging for candidates. The first equation was often answered correctly, although some candidates used sodium hydroxide rather than potassium hydroxide in their response. The second equation was frequently incorrect. Candidates frequently missed a hydrogen from the structure for methanolic acid or did not recognise that hydrogen was a product. Many candidates did not account for magnesium having a 2+ charge when working out the product. For the third equation, the majority of candidates identified that carbon dioxide and water would be produced but were unable to give the correct formula of the salt as they did not interpret the information given regarding the R group.
			Total	**4**	
27	a	i	Oxidation and reduction of the same **element**✓ 'Atom' is insufficient for element	1 (AO1.1 ×1)	**ALLOW** 'chlorine' **OR** '*Cl*' for same element **IGNORE** 'species' for 'element' **<u>Examiner's Comments</u>** Candidates answered this question well and most were given the mark. Where candidates didn't receive credit, it was mainly because they used the term 'same atom' instead of 'same element'. Some less successful responses responded with completely incorrect chemistry and had clearly not learnt this specification content.
		ii	**Equation** $Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$ ✓ **Redox:** *Cl* is oxidised from 0 (in Cl_2) to +1 in NaC*l*O ✓ *Cl* is reduced from 0 (in Cl_2) to -1 in NaC*l*/HC*l* ✓ **IGNORE** oxidation numbers shown in equation *(treat as rough working)* **BUT** If **no** oxidation numbers in explanation, *look at equation for oxidation numbers*	3 (AO2.6×1) (AO2.1×2)	**DO NOT ALLOW** $Cl_2 + NaOH \rightarrow NaClO + HCl$ **ALLOW ECF** from HCl in equation **ALLOW** 1 out of 2 redox marks if NaClO AND NaCl omitted, i.e. *Cl* is oxidised from 0 to +1 **AND** *Cl* is reduced from 0 to -1 **ALLOW** 1 out of 2 redox marks if oxidation number changes are **BOTH** correct ...BUT reduction/oxidation is incorrectly assigned, i.e. *Cl* is reduced from 0 (in Cl_2) to +1 in NaC*l*O *Cl* is oxidised from 0 (in Cl_2) to -1 in NaC*l*/HC*l* **General: ALLOW number before sign in ox no, i.e.** 1+ for +1 1- for -1 **IGNORE** ionic charges, e.g. Cl^{1+} **IGNORE** '1' (signs required) **IGNORE** references to electron loss/gain (even if wrong)

					<u>**Examiner's Comments**</u> Candidates found the equation hard, despite this reaction being specification content and the inclusion in the earlier part of the stem of 'NaClO' as one product. The correct response required candidates to realise that NaCl would be a product and to balance the resulting equation. Some did not add the balancing '2' before NaOH, and many selected HCl as the second product, a compound that would react further with NaOH to produce NaCl. The explanation worked the same whether NaCl or HCl had been identified as the second product. There were some excellent responses, providing the correct oxidation number changes, linking these to the species involved and identifying the changes as either oxidation or reduction. Two explanation marks were available with marks not being given for omission of one of the three features described above. Exemplar 2  This exemplar has been included to emphasise the points made above. It was only possible to award this response 1/3 marks. The equation shows the common error of the second chlorine-containing product being HCl and not NaCl: 0 marks The candidate has identified the oxidation number changes and has linked these to the correct species. The last statement in brackets is correct but the candidate has not communicated which oxidation number change is oxidation and which is reduction: 1/2 marks
	b		**Identification of halide** Add (aqueous) silver nitrate **OR** $AgNO_3$ **OR** Ag^+/silver ions ✓ **Observations - mark independently** Chloride/Cl^- gives white precipitate Bromide/Br^- gives cream precipitate Iodide/I^- gives yellow precipitate ✓ **Precipitate/solid seen at least once** **Equation for at least one halide** e.g. $Ag^+ + Cl^- \rightarrow AgCl$ **ALLOW** $Ag^+ + X^- \rightarrow AgX$ ✓ ***IGNORE*** *state symbols (ppt already*	5 (AO3.3×3 AO3.2×2)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** addition of HNO_3 but HCl **CONs** $AgNO_3$ **IGNORE** references to solubility in NH_3 (dil or conc), even if incorrect **ALLOW** chlorine for chloride, etc **ALLOW** equation with Br^- **OR** I^- e.g. $Ag^+ + Br^- \rightarrow AgBr$ **ALLOW** full/partial equations, e.g. $AgNO_3 + Cl^- \rightarrow AgCl + NO_3^-$ **ALLOW** explanation for identification: i.e.

			assessed) **Identification of B and C** **B**: NaBr **OR** sodium bromide ✓ **C**: $CaCl_2$ **OR** calcium chloride ✓		**B (Group 1):** Subtract molar/atomic mass of halide/Br from number in range 100–115/molar mass of B ✓ **C (Group 2):** Subtract **2** × molar/atomic mass of halide/Cl from number in range 100–115/molar mass of **C** ✓ **ALLOW** displacement by addition of halogen ✓ 2 correct colours in water or organic solvent ✓ Equation, e.g. $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ ✓ **Examiner's Comments** Candidates generally answered the first part of this question well. Most candidates were able to identify silver nitrate (or a halogen displacement method), to describe the expected observations, supported with mainly correct ionic equations. Candidates found it much harder to identify B and C as NaBr and $CaCl_2$. They could do this in various ways by matching possible formula with the provided molar mass ranges. The mark scheme did allow marks to be given when candidates described the identification process, although this was often very muddled, so, only the most able few candidates fully identified the unknown B and C.
			Total	**9**	
28			**B**	1(AO2.1)	**Examiner's Comments** Although two steps were required to solve this problem, most candidates answered this question correctly. Candidate annotations showed that many identified element X as being in Group 2 and even as magnesium. The correct formula of XCl_2 (B) then usually followed.
			Total	**1**	
29			**D**	1(AO2.6)	**Examiner's Comments** Candidates found this question very difficult. B was the main distractor, obtained by multiplying the number of moles (4) by the Avogadro constant. Only the highest-attaining candidates realised that the question asked for the number of **ions** and multiplied the answer to B by 3 to obtain option D. The lesson here is to

					consider carefully any bold text in the question (**ions**).
			Total	**1**	
30	a	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 2.53(g) award 5 marks** **---** **$[H^+]$** = $10^{-13.12}$ **OR** 7.58..... × 10^{-14} (mol dm^{-3}) ✓ $[OH^-] = \frac{1 \times 10^{-14}}{7.58........ \times 10^{-14}}$ **OR** 0.1318 .... (mol dm^{-3}) ✓ $n(OH^-)$ in 250 cm^3 = $\frac{0.1318.....}{4}$ **OR** 0.0329...... (mol) ✓ $n(Ba(OH)_2)$ or $n(BaO)$ = $\frac{0.0329.......}{2}$ **OR** 0.0164….. (mol) ✓ **Mass of BaO** = 0.0164..... × 153.3 = 2.53 (g) **3SF** ✓	5 (AO2.4×5)	**ALLOW ECF and 3SF throughout.** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **---** Calculator: 7.58577575 × 10^{-14} Calculator: 0.1318256739 **ALLOW** alternative approach using pOH for first 2 marks. $p[OH^-]$ = 14 − 13.12 = 0.88 $[OH^-]$ = $10^{-0.88}$ = 0.1318….. Calculator: 0.03295641846 0.033(0) comes from $[OH^-]$ = 0.132 Calculator: 0.01647820923 Calculator: 2.526109475 **Common errors 4 marks** 5.05g Not dividing by 2 2.82g Use of M_r for $Ba(OH)_2$ 5.06g rounds to 0.132 in M2 then not dividing by 2 **3 marks** 5.65g not dividing by 2 and using Mr for $Ba(OH)_2$ **Examiner's Comments** Although few candidates got the correct final answer, however almost all achieved some marks from this calculation through error carried forward, with marks spread across the available range. Almost all candidates were able to find the concentrations of hydrogen and hence hydroxide ions. A few candidates successfully used $p[OH^-]$ method. Most were able to calculate the moles of hydroxide ions in $250cm^3$. Many then did not realise the need to half this number to

					find the moles of barium, and/or used the Mr for barium hydroxide instead of barium oxide.
		ii	$Ba^{2+}(aq) + 2H^{+}(aq) + SO_4^{2-}(aq) + 2OH^{-}(aq)$ $\rightarrow BaSO_4(s) + 2H_2O(l)$✓	1 (AO3.2)	**ALLOW** multiples **ALLOW** $H^{+}(aq) + OH^{-}(aq) \rightarrow H2O(l)$ **OR** $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ <u>**Examiner's Comments**</u> This question was answered well, with many candidates giving one of the equations in the 'ALLOW' part of the mark scheme. Those candidates who did not gain this mark gave full equations or missed out state symbols.
	b	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 731(g) award 3 marks** **---** ***n*(Z)** $n(Ca_5NH_4(NO_3)_{11} \cdot 10H_2O) = \frac{1500}{1080.5}$ **OR** 1.388246… ✓ **Mass of limestone** *n*($CaCO_3$) = 1.388246.... × 5 **OR** 6.94123& **AND** mass $CaCO_3$ = 6.94123.... × 100.1 **OR** 694.8 g ✓ mass limestone = $\frac{694.8 \times 100}{95.0}$ = 731 g (**3SF**) ✓	3 (AO2.6×3)	**ALLOW ECF throughout** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **DO NOT ALLOW** 100 for M_r of $CaCO_3$ **Common errors** **2 marks** 146g no x 5 for moles of $CaCO_3$ 660g use of 95.0/100 29.3g divide by 5 rather than x5 <u>**Examiner's Comments**</u> This proved a difficult question for most candidates. Most were able to correctly calculate the moles of fertiliser by converting kg to g. The next step was to deduce that 5 moles of calcium carbonate would be required for each mole of Z and multiply by 5, rather than the common error of dividing by 5. Few candidates were able to multiply by 100/95, to account for the impurities in limestone, with many multiplying by 95/100.
		ii	$Mg_3Ca(CO_3)_4$ (s) + 8HC*l*(aq) →	2 (AO2.6×2)	**ALLOW** multiples

			$3MgCl_2(aq) + CaCl_2(aq) + 4H_2O(l) + 4CO_2(g)$ Correct formulae ✓ Balanced **AND** state symbols ✓		**M2** dependent on **M1** **IGNORE** incorrect state symbol for $Mg_3Ca(CO_3)_4$ **Examiner's Comments** This was another very challenging question using an unfamiliar mineral. Most candidates identified a formula of salts containing both magnesium and calcium, or carbonates of the separate elements. Only the most successful candidates were able to give the correct formula. Common errors, for those who solved the formulae, were the use of "4"HCl in balancing and the absence of state symbols.
			Total	**11**	
31	a	i	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ ✓	1(AO2.6)	**IGNORE** state symbols, even if wrong **ALLOW** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2(H_2O)_4 + 2H_2O$ **OR** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ **Examiner's Comments** Most students scored this mark, although several gave no response.
		ii	**Explanation of the brown precipitate** The brown ppt is $Fe(OH)_3$ **OR** $Fe(OH)_2$ loses electrons/ $Fe(OH)_2$ oxidised ✓ **Comparison of *E* values** (*E* of) Fe/Redox system 1 is more negative/less positive (than *E* of O_2/redox system 2) **OR**	4(AO3.1×4)	**ORA** **ALLOW** Fe^{2+} is oxidised to Fe^{3+} **ALLOW** Fe **ALLOW** E_{cell} is (+) 0.96V **IGNORE** 'lower/higher' **For equilibrium shift** **ALLOW** E_{cell} is +ve therefore the reaction is feasible. **OR** Direction of half equation correctly written.

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>(E of) O_2/Redox system 2 is more positive/less negative

(than E of Fe/redox system 1) ✓

Equilibrium shift

More negative/less positive OR Fe system OR Redox system

1 shifts left

OR

More Positive/less negative OR O_2 system OR Redox system

2 shifts right ✓

Equation
$4Fe(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Fe(OH)_3(s)$ ✓</td>
<td></td>
<td>ALLOW multiples
ALLOW equilibrium
IGNORE state symbols, even if wrong
DO NOT ALLOW uncancelled species

<u>Examiner's Comments</u>

Although a spread of marks across the full available range was seen, a good proportion of candidates gained 3 or 4 marks. Most candidates were able to produce a balanced equation, but candidates should take care cancelling out any species present on both side of the equation, e.g. the hydroxide ions. A common error within the formula of iron (III) hydroxide was to place the number of hydroxide ions within the brackets, e.g. $Fe(OH_3)$. Candidates are advised to read the instructions contained within the equation and to use or comment on all the data presented. When commenting on electrode potentials, candidates should avoid the use of higher/lower as these phrases are meaningless due to the negative signs involved.</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td></td>
<td>Level 3 (5–6 marks)
Reaches a comprehensive conclusion to determine the correct formulae of almost all of B, C, D, E, F and G.
AND
most correct equations and identifies some changes in oxidation number
AND
Calculation of M_r of the gas

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)
Reaches a conclusion to determine the correct formulae of at least half of B, C, D, E, F and G.
AND EITHER
some correct equations
OR
Any one correct equation and a relevant change in oxidation number
OR
any one correct equation and a correct calculation of the M_r</td>
<td>6(AO3.1×3
AO3.2×3)</td>
<td>Indicative scientific points may include

<table>
<tr><td></td><td>Formula</td></tr>
<tr><td>B</td><td>$CuCl_4^{2-}$
OR
$[CuCl_4]^{2-}$</td></tr>
<tr><td>C</td><td>$[Cu(H_2O)_6]^{2+}$
OR
$CuSO_4$</td></tr>
<tr><td>D</td><td>SO_2</td></tr>
<tr><td>E</td><td>$Cu(NO_3)_2$
OR
$[Cu(H_2O)_6]^{2+}$</td></tr>
<tr><td>F</td><td>CuI</td></tr>
<tr><td>G</td><td>I_2</td></tr>
</table>

Experiment 1

Equation

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$
$[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$</td>
</tr>
</table>

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)
Reaches a simple conclusion to determine the correct formulae of **some** of **B**, **C**, **D**, **E**, **F** and **G**
OR
The correct formulae for 1 of **B**, **C**, **D**, **E**, **F** and **G** with correct equation or calculation.

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.

Experiment 2

Evidence
$n(\mathbf{D}) = \frac{45}{24000} = 1.875 \times 10^{-3}$
Molar mass (**D**) = $\frac{0.12}{1.875 \times 10^{-3}} = 64$
Equation
$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$

Oxidation numbers
Cu 0 → Cu +2; S +6 → S +4

Experiment 3

Equation

$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$

$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$
OR
$2Cu(NO_3)_2 + 4KI \rightarrow 2CuI + I_2 + 4KNO_3$

Oxidation numbers

Cu +2 → Cu +1; I −1 to 0

__**Examiner's Comments**__

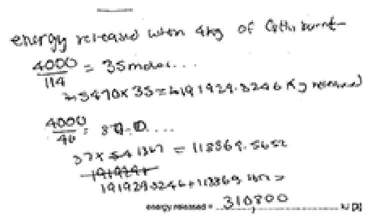
Answers were distributed across all 3 levels of achievement. Most of the candidates managed to identify at least some of the substances. Of the equations, the reaction of copper (II) oxide with nitric acid was most regularly seen correct, although many students could also represent the ligand replacement in Experiment 1. Many candidates were able to calculate Mr for gas D but some of those suggesting SO_2 as a possible formula preferred to have an equation in experiment 2 producing hydrogen. A few candidates used the M_r to suggest that the gas was $2O_2$ and as such candidates found the equation between copper and sulphuric acid challenging. A good number of candidates identified F and G, recognising what they had learned from their work on redox titrations, and some were able to reproduce the equation. Incorrect formula of copper (I) iodide (CuI_2) was a common error. Many candidates made no attempt at identifying changes in oxidation states. Candidates

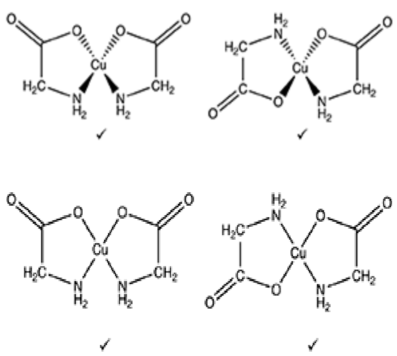
					are advised to address all parts of the question in order to access the higher levels and to allow sufficient time to attempt the LoR questions.
			Total	**11**	
32			**C**	1(AO1.2)	**Examiner's Comments** This question was quite well answered with many candidates identifying the correct response as C. Candidates had to link the volume of gas with the moles of each gas and then match to the stoichiometry of the equation. Some candidates calculated the moles of gas and then appeared to choose an answer at random.
			Total	**1**	
33			**B**	1(AO1.2)	**Examiner's Comments** This was generally well answered. The key to candidates quickly arriving at the correct answer of B was to focus on identifying the number of CN^- ions and calculating the total of 18 negatively charge ions. More successful candidates could clearly see that the combination of iron ions must add up to the total of 18 positively charged ions. Some candidates lost time here by working out formulae and trying to write out the structure of Prussian blue.
			Total	**1**	
34	a	i	Any value in range: 8–14 ✓	1 (AO1.1)	**Examiner's Comments** Most candidates gained this mark. The most common incorrect response was pH 7 with a few giving a pH value of less than 7.
		ii	White precipitate/white solid ✓ $BaSO_4$ ✓	2 (AO 3.1) (AO 3.2)	**Examiner's Comments** Most candidates were able to give the formula of the barium compound as $BaSO_4$. However, they did not recognise that this would cause a white ppt to be seen, presumably as not in the context of qualitative ions testing. Many candidates said they would see bubbling/fizzing. Some gave a colour change as they were

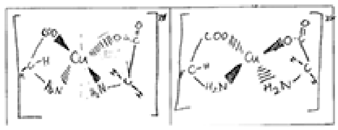
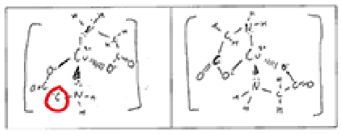
					possibly considering what would be seen if an indicator is present. Others mentioned a precipitate but with no colour given. Some candidates gave the incorrect formula, such as Ba_2SO_4 or $Ba(SO_4)_2$, again showing the importance of practising writing formulae. In addition, some candidates wrote out the whole equation for the reaction. **OCR support** We have produced a topic support pack to assist with learning about the reaction of group 2 elements and their compounds: http:/www.ocr.org.uk/Images/364103-chemistry-of-group2.docx
	b	i	$Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ All formulae and balancing correct ✓	1 (AO2.6)	**IGNORE STATE SYMBOLS** **ALLOW** multiples **IGNORE** state symbols (even if wrong) **<u>Examiner's Comments</u>** Around half of all candidates did not score this mark. The most common error was giving SrO as the product rather than the hydroxide. Other errors included incorrect balancing (missing 2 on H_2O, SrOH as the formula of the hydroxide and no hydrogen formed (often giving H_2O instead)). **Assessment for learning** Regular practice writing formulae and balancing chemical equations will help to consolidate these concepts, avoiding basic errors such as giving formula of group 2 hydroxide as SrOH.
		ii	**Oxidation** Sr from **0** to **+2** ✓ **Reduction** H from **+1** to **0** ✓	2 (AO 2.1 × 2)	**ALLOW** 2+ for +2 and 1+ for +1 '+' is required in +2 and +1 oxidation numbers

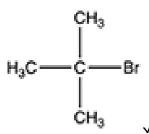
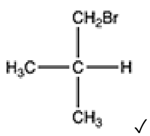
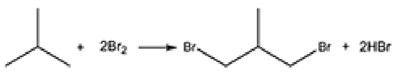
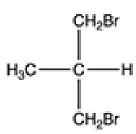
					ALLOW H_2 for hydrogen **ALLOW** 1 mark for elements **AND** all oxidation numbers correct but oxidation and reduction wrong way round **OR** not given. **IGNORE** numbers around equation in **(i)** *(treat as rough working)* **<u>Examiner's Comments</u>** Most candidates managed to score at least 1 mark for this question. The most common reason for losing a mark, despite demonstrating a good understanding of redox, was stating that H changed from +2 to 0 (need to give oxidation number per atom). Other errors seen included only giving change for Sr, descriptions in terms of electrons rather than oxidation numbers, Sr change from 0 to +1 (linked to SrOH), oxygen being reduced rather than H and mixing up oxidation/reduction or not specifying.
		iii	*Atomic radius* Ca has smaller atomic radius **OR** fewer shells ✓ *Effect of nuclear charge/shielding* Ca has **less/decreased** shielding ✓ *Nuclear attraction* Ca has greater nuclear attraction (for electrons) **OR** Ca has a higher ionisation energy **OR** more energy is required to lose the outer electrons✓	3 (AO 1.2) (AO 1.2) (AO 1.2)	**FULL ANNOTATIONS MUST BE USED** --- **ORA in terms of Sr** **Comparison** needed for each mark. **ALLOW** 'fewer energy levels' **ALLOW** 'electrons closer to nucleus' **IGNORE** fewer orbitals **OR** fewer sub-shells **OR** different shell **ALLOW more** electron repulsion from inner shells **IGNORE** nuclear charge/effective nuclear charge **ALLOW** 'less nuclear pull' **OR** 'electrons held less tightly' **<u>Examiner's Comments</u>**

					Most candidates gained some marks here although a significant proportion were unable to score all 3 marks covering atomic radius, shielding, nuclear attraction/IE. The mark most often missed was for shielding. Some candidates did not answer the question asked and gave the trend down the group so could not be given marks unless they made it clear Sr is below Ca in the group. Care must be taken to answer question asked not similar questions they have seen before. The best responses were those with direct comparative statements, e.g. "Ca has a smaller atomic radius than Sr". It is worth noting that harder/easier to lose electrons didn't gain marks, but was seen fairly frequently, as response needs to be in terms of energy required or linked to nuclear attraction.
			Total	**9**	
35		i	C_8H_{18} + C_2H_5OH + 15½ O_2 → 10 CO_2 + 12 H_2O ✓	1 (AO2.6)	**ALLOW** multiples e.g. 2 C_8H_{18} + 2 C_2H_5OH + 31 O_2 → 20 CO_2 + 24 H_2O **ALLOW** $C_{10}H_{24}O$ for C_8H_{18} + C_2H_5OH *Combining ethanol and octane!* **<u>Examiner's Comments</u>** Most candidates attempted to write an equation for the combustion of the 1:1 molar mixture of octane and ethanol. The formulae of C_8H_{18} and C_2H_5OH were usually seen although some candidates combined these as a 'mixture formula' of $C_{10}H_{24}O$ (which was accepted). The balancing of the equation using 15½O_2 was the hardest part of the equation and many different balancing numbers for O2 were seen (10CO_2 and 12H_2O where usually correct). Less successful responses often attempted a combustion equation using octane OR ethanol, but not both. This is not an easy equation to construct, and the context was novel. Overall candidates made a good attempt at this question.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 341850 to 2 SF or more award 3 marks** --	3 (3 ×AO2.2)	**IGNORE** sign throughout **ALLOW** approach based on mass for 2nd mark *m*(C_8H_{18}) = (114/160) × 8000 = 5700 g

			---- $M(C_8H_{18})$ = 114 **AND** $M(C_2H_5OH)$ = 46 **OR** 1 mol C_8H_{18} + 1 mol C_2H_5OH has mass of 160 g ✓ 50 mol C_8H_{18} **OR** 50 mol C_2H_5OH **OR** 50 mol (C_8H_{18} + C_2H_5OH) **OR** 8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol C_2H_5OH ✓ Energy = (50 × 5470) + (50 × 1367) **OR** 50 × (5470 + 1367) **OR** 50 × 6837 **OR** 273500 + 68350 **=341850(kJ)✓**		**AND** $m(C_2H_5OH)$ = (46/160) × 8000 = 2300 g Energy = 5700/114 × 5470 + 2300/46 × 1367 = 341850 (kJ) **ALLOW 2 SF or more** correctly rounded --- <u>**Common errors**</u> **310800 → 2 marks** *Use of equal masses (4 kg) of C_8H_{18} & C_2H_5OH (rather than equal moles)* **Example**  <u>**Examiner's Comments**</u> This question took the novel context introduced in 5b a stage further by considering the energy released during the combustion of this fuel. Most candidates were able to obtain some credit, and many obtained the correct energy of 341,850 kJ. The commonest error was for candidates to assume that the 8 kg mixture would contain 4 kg of octane and 4 kg of ethanol, rather than an equal moles of each. Such an approach could still be partly given marks by ECF, provided that the method was sound and clear.
			Total	**4**	
36		i	***Bond angles*** H_2NCH_2COONa, bond angle = 107° **AND** $HOOCCH_2NH_3Cl$, bond angle = 109.5° ✓ ***Number of electron pairs*** ***Mark independently of angles*** In NaOH/107°, (NH_2 has) **3** bonded pairs **/ 3** bonds **AND** **1** lone pair ✓ In HCl/109.5°, (NH_3^+ has) **4** bonded pairs / **4** bonds ✓	3 (3 ×AO1.2)	**ALLOW** 107 ± 0.5 **ALLOW** 109 **OR** 110° **ALLOW** NH_2 has **4** pairs, one of which is a lone pair **For bonded pairs/bonds** **ALLOW bonded** groups, atoms, elements, regions ***Bonded** essential* **IGNORE** electron region **OR** electron density **IGNORE** NH_3 has no lone pairs

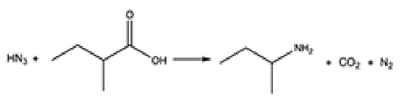
					IGNORE lone pairs repel more (than bonded pairs) **IGNORE** shapes, even if wrong **ALLOW** bp for bonded pair and lp for lone pair **<u>Examiner's Comments</u>** This question required candidates to apply their knowledge and understanding of bond angles and electron pair repulsion of NH_3 and NH_4^+ to amino acid salts. The best candidates rose to this challenge and secured all 3 marks for correct bond angles and explanations in terms of the numbers of bonded and lone pairs around the N atoms. Overall, candidates found this question quite difficult. Many different bond angles were predicted, with 120° being the commonest incorrect H-N-H bond angle in H_2NCH_2COONa. The explanation for 120° was in terms of three bonding pairs and no lone pairs. 104.5° was also seen, presumably relating H_2N to H_2O. The 109.5° bond angle was correct more often, as was its explanation in terms of 4 bonding pairs. Many successful responses showed working on diagrams in which bonded and lone pairs had been included. This strategy will have helped candidates in their conclusions.
		ii	**Equation:** **2** $H_2NCH_2COOH + Cu(CH_3COO)_2$ $\rightarrow Cu(H_2NCH_2COO)_2$ + **2** CH_3COOH ✓ **Structures**  Ligands **must** shown as bidentate rings	3 (AO2.6) (2 ×AO2.5)	**ALLOW** molecular formulae or mixture, e.g. $2C_2H_5NO_2 + CuC_4H_6O_4 \rightarrow CuC_4H_8N_2O_4 + 2C_2H_4O_2$ **IGNORE** charges **i.e. IGNORE** wrong or missing charges in ionic compounds if formula is correct/ e.g. **ALLOW** $Cu(CH_3COO^-)_2$, $Cu^+(CH_3COO^-)_2$ **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** charges **ALLOW** arc to represent $-CH_2-$ between: C of C=O and NH_2

			IGNORE connectivity for NH_2 **BUT** connectivity **must** be to O of COO		**ALLOW** 1 mark for 2 'correct' structures shown as tetrahedral e.g.  **IGNORE** missing Hs on C, e.g.  **<u>Examiner's Comments</u>** Candidates were asked to predict an unfamiliar equation from provided information and to draw structures of square planar complexes containing an amino acid. Candidates found the structures easier than the equation, with many drawing 3D structures with 2 out-wedges and 2 in-wedges and attaching the NH_2 and COO groups correctly. It was also common to see a 'criss-cross' orientation, looking down on the complex, which is easier to draw. Many candidates connected the NH_2 and COO groups next to, and across from, each another in the isomers. A common error was for candidates to rotate their first structure, to produce a second drawing of the first structure. Less successful responses often tried to attach NH_2 and COO groups but with no CH_2 between the groups to produce a cyclic attachment. A minority of candidates ignored 'square planar' and drew tetrahedral structures instead. The equation proved to be very difficult, the commonest error being omission of the '2' balancing numbers for H_2NCH_2COOH and CH_3COOH. The formulae for ethanol or propanoic acid were also often seen for ethanoic acid. Candidates are advised to check all formulae and then to check balancing, the golden rules for successfully constructing all equations.
			Total	**6**	

37			$5\ H_2S + 2\ MnO_4^- + 6\ H^+ \rightarrow 2\ Mn^{2+} + 5\ S + 8\ H_2O$ **OR** $40\ H_2S + 16\ MnO_4^- + 48\ H^+ \rightarrow 16\ Mn^{2+} + 5\ S_8 + 64\ H_2O$ Any **FIVE** correct species ✓ Correct balanced equation ✓	2 (AO3.2)	**ALLOW** multiples e.g. $2\frac{1}{2}\ H_2S + MnO_4^- + 3\ H^+ \rightarrow Mn^{2+} + 2\frac{1}{2}\ S + 4\ H_2O$ $20\ H_2S + 8\ MnO_4^- + 24\ H^+ \rightarrow 8\ Mn^{2+} + 2\frac{1}{2}\ S_8 + 32\ H_2O$ **IGNORE** extra species containing: Mn, H, S and O **ONLY** **BUT ALLOW** $KMnO_4$ on LHS, forming K^+ on RHS **IGNORE** electrons **IGNORE** state symbols **<u>Examiner's Comments</u>** Candidates needed to interpret the information provided and to use this as the basis for their redox equation. The clue of a yellow product proved to be very difficult to interpret as being sulphur. The equation then required H^+ to be added as a reactant ('acidified' in the information) and H_2O as the other product. Balancing required use of oxidation numbers. Candidates found this equation very difficult and relatively few correct equations were seen. The mark scheme did allow 1 mark for any correct five species but the correct equation proved to be challenging in demand.
			Total	**2**	
38	a		 ✓  ✓	2 (AO2.5 × 2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
	b		 Structure of organic product ✓ Complete balanced equation ✓	2 (AO2.5) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous, e.g. 
			Total	**4**	
39	a		Formula: $CuCO_3$ ✓	2 (AO1.2) (AO2.6)	**IGNORE state symbols** **ALLOW** formula within equation.

			$CuCO_3 + 2HNO_3 \rightarrow Cu(NO_3)_2 + CO_2 + H_2O$ ✓		**ALLOW** other copper(II) compounds which can react with nitric acid to form a gas e.g. CuS, $CuSO_3$ for mark 1, with correct equation for mark 2. e.g.$CuSO_3 + 2HNO_3 \rightarrow Cu(NO_3)_2 + SO_2 + H_2O$
	b		$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$	1 (AO2.6)	**ALLOW** multiples State symbols are required
	c		starch (solution) **AND** blue-black to colourless ✓	1 (AO1.2)	**ALLOW** blue **OR** black **OR** purple for colour of mixture **ALLOW** blue colour disappears (to colourless) **IGNORE** 'clear' **IGNORE** 'colorimetry
	d		**FIRST CHECK THE ANSWER ON ANSWER LINE** If answer = 1.35 award 4 marks --- *n*($S_2O_32^-$) = $0.0200 \times \frac{26.55}{1000}$ = 5.31×10^{-4} (mol) ✓ *n*(I_2) = 2.655×10^{-4} OR *n*(Cu^{2+})= 5.31×10^{-4} (mol) ✓ *m*(Cu/Cu^{2+}) in ore = $63.5 \times 5.31 \times 10^{-4}$ = 0.0337….. (g) ✓ percentage = $\frac{0.0337....}{2.50} \times 100$ = 1.35 (%) ✓ (**3SF** required)	4 (AO2.8×5)	***FULL ANNOTATIONS MUST BE USED -*** --- **ALLOW ECF** throughout If 1:2 ratio for I_2:Cu^{2+} not used check ratio in b) and allow **ECF** **IGNORE** rounding errors after 3 SF Calculator: 0.0337185 **ALLOW** 3 SF (0.0337) up to calculator value **ECF** dependent on the use of a calculated mass of Cu/Cu^{2+} **Examiner's Comments** This was a percentage by mass calculation. Many candidates correctly calculated the number of moles of thiosulphate and used the ratio to calculate the moles of iodine. Many candidates then either linked this, incorrectly, to the number of moles of iodide or used an incorrect mole ratio to find the moles of Cu^{2+}.Multiplication by the relative formula mass of copper was well understood and some candidates gained error carried forward marks for their calculation of the percentage.
	e	i	Lower **AND** smaller titre ✓	1 (AO3.4)	**ALLOW** less I_2 produced / less Cu^{2+} reacts
		ii	The same **AND** burette measures by difference ✓	1 (AO3.4)	**ALLOW AW**
	f		Any two of the following: Make up a (standard solution) from	2 (AO3.4x 2)	

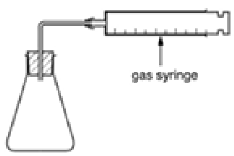
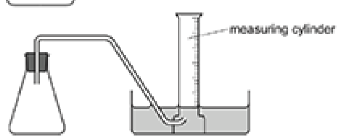
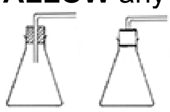
			Step 2 to a stated volume (e.g. 250 cm^3) OR Repeat titrations **AND** Take mean of concordant/closest titres/ identify anomalies OR lower $[S_2O_3]^{2-}$ to increase titre volume (to reduce the percentage error). OR higher $[S_2O_3]^{2-}$ so not to refill the burette. OR Use a 3 dec place balance (to reduce the percentage error).		
			Total	**12**	
40	a	i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.75 award 2 marks -- $[H^+]^2 = K_a \times [HN_3]) = 2.51 \times 10^{-5} \times 0.125$ $[H^+] = \sqrt{}(K_a \times [HN_3])$ $[H^+]^2 = 2.51 \times 10^{-5} \times 0.125$ **OR** $[H^+] = \sqrt{}(2.51 \times 10^{-5} \times 0.125)$ **OR** $[H^+] = 1.77.... \times 10^{-3}$ (mol dm^{-3}) ✓ pH = –log 1.77…. × 10^{-3} = 2.75 (Must be to **2DP**) ✓	2 (AO2.2×2)	**ALLOW ECF** throughout **IGNORE** error with HN_3 shown as NH3 **ALLOW** pH mark by **ECF** **ONLY** if 2.51 × 10^{-5} × 0.125 used **AND** pH < 7 -- **Common errors (Must be to 2 DP)** pH = 5.50 → 1 mark (*No square root*) $[H^+] = 6.26 \times 10^{-4}$ from √ (2.51 × 10^{-5}) × 0.125 pH = 3.20 → 1 mark $[H^+] = 8.87 \times 10^{-6}$ from √ (0.125) × 2.51 × 10^{-5} pH = 5.05 → 1 mark **<u>Examiner's Comments</u>** Most candidates found this pH calculation easy and most obtained a pH of 2.75 for both marks.
		ii	• Correct equation ✓ • Correct acid–base pair labels for correct equation ✓	2 (AO1.2×2)	**ALLOW** 1 mark for one correct acid–base pair **WITH** correct labels

			$HN_3 + H_2O \rightleftharpoons N_3^- + H_3O^+$ ✓ **A1** **B2** **B1** **A2** ✓ **OR** **A2** **B1** **B2** **A1**		e.g. H_2O H_3O^+ **WITH** B1 A1 **OR** B2 A2 **<u>Examiner's Comments</u>** This unfamiliar acid–base pair question was answered comparatively well. Most candidates identified one correctly labelled acid–base pair, usually H_3O^+ and H_2O. The higher-attaining candidates were able to write the correct equation and to identify both acid–base pairs.
		iii	Structure of 2-methylbutanoic acid ✓ Structure of organic product (primary amine) ✓ CO_2 **AND** N_2 as products ✓  	3 (AO3.2×2) (AO2.6)	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous **Common error** With NH_3, → $CO_2 + H_2$ **ALLOW ECF** for equation using a different amine isomer of the organic product *e.g.* $(CH_3)_2CHCH_2NH_2$ **DO NOT ALLOW ECF** from unbranched species, e.g. $CH_3CH_2CH_2NH_2$ **IGNORE** HN_3 in equation, even if missing **IGNORE** poor connectivity to all groups **<u>Examiner's Comments</u>** Candidates were expected to interpret information for an unfamiliar organic reaction and to write a balanced question. The information included important clues which were sometimes ignored, showing the importance of using any information provided. The structure of 2-methylbutanoic acid was usually correct although many candidates did show 3-methylbutanoic acid instead, numbering from the wrong end of the chain. The amine structure proved to be more difficult with many showing an amide instead. Even when an amine was shown, it often included four C atoms instead of three. Finally, candidates were told that the two gases (N_2 and CO_2) are present in the atmosphere. Many candidates clearly did not use this clue, included substances that are not atmospheric gases such as H_2,

					H_2O and NH_3. As always, the advice is to use the information provided – it often includes hints to help candidates. **Misconception** Branched and substituted carboxylic acids are named counting from the start of the main stem, e.g. In Q5(b)(iii), 2-methylbutanoic acid is $CH_3CH(CH_3)CH_2COOH$. The correct name is obtained by starting from the carbon atom with the functional group. i.e. The COOH carbon in number 1: 2-methylbutanoic acid is $CH_3CH_2CH(CH_3)COOH$. The same rule is used for all organic compounds, e.g. 2-methylbutanal is $CH_3CH_2CH(CH_3)CHO$ and **not** $CH_3CH(CH_3)CH_2CHO$
	b		**Level 3 (5–6 marks)** Reaches a comprehensive conclusion to determine the correct formulae of **almost all** of **E**, **F**, **G**, **H**, **I** and **J** *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Reaches a sound conclusion to determine the correct formulae of **at least half** of **E**, **F**, **G**, **H**, **I** and **J** *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Reaches a simple conclusion to determine the correct formulae of **some** of **E**, **F**, **G**, **H**, **I** and **J** *There is an attempt at a logical structure with a line of reasoning.* *The information is in the most part relevant.*	6 (AO3.1×2) (AO3.2×4)	**Indicative scientific points may include:** <u>**Identify of E, F, G, H, I and J**</u> • **E** Cu/copper • F: H_2O/water • **G**: N_2/nitrogen • **H**: CH_3COCl **OR** $ClCH_2CHO$ **OR** C_2H_3OCl • **I**: CH_3CONH_2 **OR** H_2NCH_2CHO • **J**: NH_4Cl/ammonium chloride Examples of reasoning <u>**Working**</u> $n(CuO) = \frac{4.77}{(63.5 + 16)} = 0.06$ (mol) $M(\mathbf{E}) = 3.81 \div 0.06 = 63.5$ $n(\mathbf{G}) = \frac{480}{24000} = 0.02$ $M(\mathbf{G}) = \frac{0.560}{0.02} = 28$ (g mol^{-1}) <u>**Infrared spectrum**</u> I contains • C=O (~1700 cm^{-1}) • NH_2 (~3200–3400 cm^{-1}) <u>**Equations**</u> $3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$ $CH_3COCl + 2NH_3 \rightarrow CH_3CONH_2 + NH_4Cl$

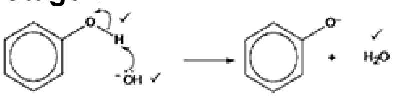
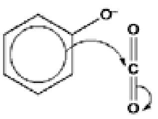
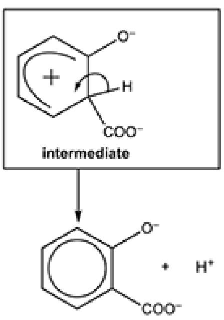
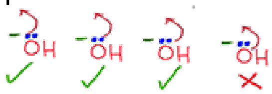
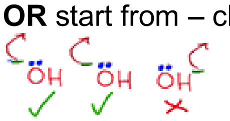
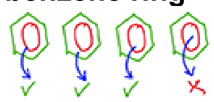
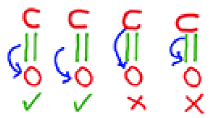
			0 marks *No response or no response worthy of credit.*		**OR** $ClCH_2CHO + 2NH_3 \rightarrow H_2NCH_2CHO + NH_4Cl$ **Examiner's Comments** Candidates were supplied with information about two reactions, supported by numerical data and an IR spectrum. The reactions were novel, meaning that candidates needed to apply their knowledge and understanding to unfamiliar contexts. This is an area in which many candidates have difficulty. Candidates were required to identify six unknown substances, with Levels being determined from the number identified. The communication mark in each level was given on the clarity of the analysis of the evidence. Overall, candidates found this question difficult. For reaction 1, many identified **F** and **G** as H_2 and N_2 respectively. Identification of **E** as Cu proved to be more problematic, with $Cu(OH)_2$ and copper(II) complexes with ammonia being seen often. This was despite the mass of **E** in the supplied data being less than the mass of copper(II) oxide. For reaction 2, many identified the N–H and C=O peaks in the IR spectrum but candidates often listed all the possible peaks from the Data Sheet. The supplied clues showed that **H**, **I** and **J** were linked by the reaction of an acyl chloride with ammonia. The chloride salt **J** as NH_4Cl was seen very rarely. There were attempts at constructing equations. The equation for reaction 1 was seen by high-attaining candidates, mostly those achieving Level 3.
			Total	**13**	
41	a		**A:** Ca_3N_2 (formula required) ✓ **B:** NH_3 **OR** ammonia ✓ **C:** $Ca(OH)_2$ **OR** calcium hydroxide ✓ **Equation:** $Ca_3N_2 + 6H_2O \rightarrow 2NH_3 + 3Ca(OH)_2$ ✓	4 (AO1.1) (AO2.7×2) (AO2.6)	**IGNORE** working If **B** and **C** labels are the wrong way round **OR** missing, award 1/2 for **B** and **C** labels, i.e. for **B** $Ca(OH)_2$ **C** NH_3 1/2 marks **ALLOW** CaO_2H_2 **ALLOW** multiples for equation

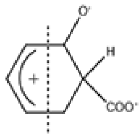
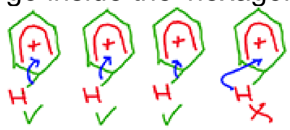
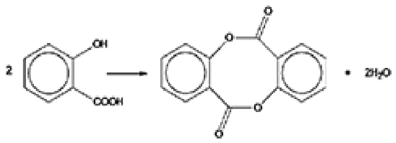
					IF C = CaO, **ALLOW ECF** for: $Ca_3N_2 + 3H_2O \rightarrow 2NH_3 + 3CaO$ **Examiner's Comments** Candidates were required to analyse provided information to identify three unknown compounds and to write an equation. Most candidates knew how to derive a formula from percentage compositions by mass and were able to identify **A** as Ca_3N_2. Candidates found it difficult to apply their knowledge and understanding to the information to identify **B** as NH_3 and **C** as $Ca(OH)_2$. Some candidates did identify **B** and **C** but did not state which was which, costing a mark. Identification of **A**, **B** and **C** usually led to a correctly balanced equation. A common mistake was identification of **C** as CaO and a 'correct' equation using CaO was allowed. Candidates are recommended to use the 'hints' in the provided information to obtain realistic possibilities for unknown substances. A reaction of H_2O with a compound containing Ca and N can only form a limited number of alkalis. Common formulae seen included H_2, NOH, NO_2, NH_4, NH_2 and these should have been instantly rejected as not being alkalis.
	b		$2CH_3CH(OH)COOH + Na_2CO_3 \rightarrow$ $2CH_3CH(OH)COONa + CO_2 + H_2O$ CO_2 and H_2O **OR** $CH_3CH(OH)COONa$ as product(s) ✓ Balanced equation correct ✓ $3CH_3CH(OH)COOH + Al \rightarrow$ $(CH_3CH(OH)COO)_3Al + 1½\ H_2$ H_2 **OR** $(CH_3CH(OH)COO)_3Al$ as product ✓ Balanced equation correct ✓	4 (AO2.6×4)	**ALLOW** multiples **IGNORE** state symbols **ALLOW** ions shown separately For CO_2 AND H_2O, **ALLOW** H_2CO_3 **ALLOW** ….$COONa^{+}$ (i.e. one of charges missing) **ALLOW** ….$COO)_3Al^{3+}$ (i.e. one of charges missing) **Examiner's Comments** Candidates needed to use their knowledge of reactions of carboxylic acids to construct two equations. Most candidates obtained 1 mark for each

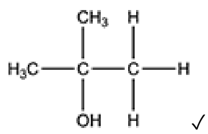
					equation by identifying CO_2 and H_2O for the reaction with Na_2CO_3 and H_2 for the reaction with Al. The second mark for each equation was much more elusive. Common errors included sodium carbonate shown as $NaCO_3$, reaction of the alcohol OH to form $–O^-Na^+$ and unbalanced equations. **AfL** Candidates are advised to take much more care when writing formulae and equations. Knowledge of the charge on common ions (such as Na^+ and CO_3^{2-}) is essential.
			Total	**8**	
42	a		**Closed system that would work** **(*Labels not required*)** Reaction apparatus with tube/side arm **AND** gas collection apparatus **AND** closed system ✓ **Labels** ***Reaction apparatus, e.g.*:** Conical flask, Buchner flask/conical flask with side arm, test-tube, boiling tube. **AND** ***Gas collection apparatus:*** (gas) syringe **OR** gas collection over water with labelled measuring cylinder / burette ✓  	2 (AO3.3× 2)	**ALLOW** small gaps provided there is an attempt to show closed system **DO NOT ALLOW** delivery tube below reaction mixture **For reaction apparatus,** • DO NOT ALLOW flask, volumetric flask, beaker, measuring cylinder • Delivery tube, bung does NOT need a label **ALLOW** labels for diagram without closed system (e.g. bung missing), i.e. 2nd mark but not 1st mark **ALLOW** any of these diagrams.  **ALLOW** a single line for the tube **IGNORE** Sealed end of delivery tube **IGNORE** size of syringe/measuring cylinder/burette **<u>Examiner's Comments</u>** Candidates to interpret the results of a practical experiment that would be similar to experiments they would have carried out.

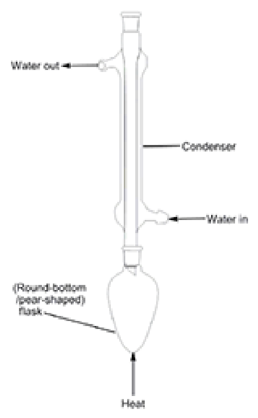
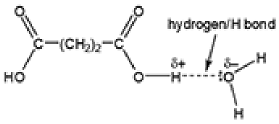
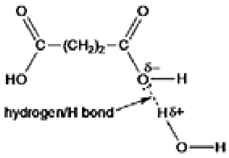
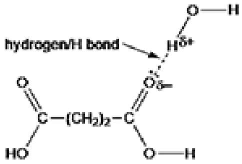
					Candidates were asked to draw a labelled diagram for a familiar practical set up. The first mark was available for an unlabelled diagram of a closed system that would work. Most candidates were given this mark. The second mark required labels of key pieces of apparatus and some candidates did not name these correctly, with conical flasks sometimes being labelled as beakers. Many diagrams were unclear, suggesting that candidates need to take much more care and time when drawing them.
	b		$n(H^2) = \frac{152}{24000}$ **OR** 6.33…. × 10^{-3} (mol) ✓ $n(Eu) = \frac{0.988}{152}$ **OR** 6.5(0) × 10^{-3} (mol) ✓ Ratio H_2 : Eu 1 : 1 **AND** Equation 2 is correct ✓ *Only **ALLOW** if n(H_2) **AND** n(Eu) are approximately equal* **ALLOW** use of ideal gas equation at a reasonable temperature and pressure. e.g. Using 100 kPa and 298 K, n(H_2) = 6.14 × 10^{-3} mol	3 (AO2.8×2) (AO3.2×1)	**152** 6.5(0) × 10^{-3} (mol) **ALLOW** 0.97(4) : 1 **ALLOW ECF** from incorrect *n*(Eu) **OR/AND** *n* (H_2) --- **ALLOW** approach that calculates mass Eu from 6.33…. × 10^{-3} mol H_2 for each equation, e.g. Equation 1: 2 × 6.33 × 10^{-3} × 152 = 1.9.. g Equation 2: 1 × 6.33 × 10^{-3} × 152 = 0.96.. g Equation 3: 2/3 × 6.33 × 10^{-3} × 152 = 0.64.. g ✓ 0.988 matched to 0.96 g and Equation 2 ✓ *Use judgment* --- **ALLOW** approach that calculates volume H_2 from 6.50 × 10^{-3} mol Eu for each equation, e.g. Equation 1: 0.5 × 24000 × 6.50 × 10^{-3} = 78 cm^3 Equation 2: 1 × 24000 × 6.50 × 10^{-3} = 156 cm^3 Equation 3: 1.5 × 24000 × 6.50 × 10^{-3} = 234 cm^3 ✓ 152 matched to 156 cm^3 and Equation 2 ✓ *Use judgment* __**Examiner's Comments**__ Candidates were required to analyse the experimental results to obtain a

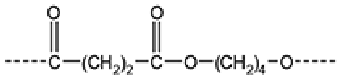
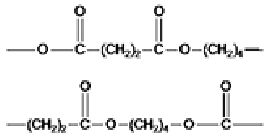
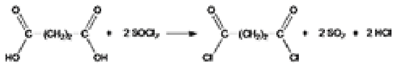
					conclusion. Most candidates calculated the moles of Eu and H_2 correctly. Candidates were then expected to conclude that Equation 2 was correct using the 1:1 ratio. Overall, this question was answered well, though some candidates omitted to show the ratio evidence.
	c		The gas volume would be larger (than at RTP) ✓ Ratio H_2 : Eu would be larger ✓	2 (AO3.4×2)	**IGNORE** effect of rate, e.g. rate increases **IGNORE** gas equation should be used to find $n(H_2)$ **ALLOW** Equation 3 linked to H_2 : Eu > 1 **<u>Examiner's Comments</u>** Candidates needed to evaluate the effect on the results and conclusion of the apparatus getting hot. Most candidates did realise that the gas volume would increase but the reason was usually in terms of a faster reaction with more successful collisions rather than expansion of gas as temperature increases. Candidates then needed to realise that the H_2 : Eu ratio would increase leading to Equation 3 to be the most likely. This conclusion proved to be elusive for most candidates.
	d		**Qual** Precipitates have different molar masses **OR** Precipitates have different formulae ✓ **Quant** Equation 2 forms precipitate with M = 186 **OR** with formula $Eu(OH)_2$ **OR** Equation 2 forms 1.86 g precipitate **OR** Molar mass M of precipitate = $\frac{\text{mass of precipitate}}{\text{moles precipitate}}$ **OR** $\frac{\text{mass of precipitate}}{\text{moles Eu}}$ **OR** $\frac{\text{mass of precipitate}}{0.01}$ ✓ ✓	2 (AO3.4×2)	**ALLOW** precipitates are EuOH, $Eu(OH)_2$ $Eu(OH)_3$ **OR** precipitates have different number of OH^- ions **ALLOW** Moles OH– = $\frac{\text{mass of precipitate} - \text{mass of Eu}}{\text{molar mass of } OH^-}$ **OR** Moles OH– = $\frac{\text{mass of precipitate} - 1.52}{17}$ **<u>Examiner's Comments</u>** Candidates found it much more difficult to evaluate the unfamiliar scenarios in (c) and (d) than the stock mole calculation in (b). Candidates found this question very difficult with many stating that the equation could be determined from the molar ratio of Eu to the precipitate, despite these being the same.
			Total	**9**	

43			D	1 (AO2.6)	
			Total	**1**	
44		i	**Stage 1**  1 mark for each curly arrow as shown. **Stage 2** Curly arrow from π-ring to C in CO_2 **AND** curly arrow from the C=O bond to O atom ✓  Correct intermediate ✓ Curly arrow from C–H bond to reform π-ring **AND** H^+ formed ✓ 	6 (AO1.1) (AO1.2) (AO2.5) (AO2.5) (AO2.5) (AO1.2)	**ANNOTATE WITH TICKS AND CROSSES** **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **Curly arrow** from OH^- must • go to the H of O–H **AND** • start from, **OR** be traced back to **any point across width** of lone pair on O of OH^-  • **OR** start from – charge–OH ion  **Curly arrow** from O–H bond must start from, **OR** be traced back to, **any part of** O–H bond and go to O **IGNORE** dipoles on O-H bond **IGNORE** Na^+ **1st curly arrow** must • go to the C of CO_2 **AND** • start from, **OR** close to **circle of benzene ring**  **2nd curly arrow** must start from, **OR** be traced back to, **any part of** C=O bond and go to O  **ALLOW 2nd** curly arrow from C=O to any O in CO_2 **DO NOT ALLOW** the following intermediate:

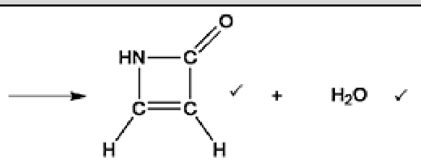
					 π-ring must cover more than half of the benzene ring structure **AND** the correct orientation, *i.e.* gap towards C with CO_2^- **ALLOW** + sign anywhere inside the 'hexagon' of the intermediate. **DO NOT ALLOW** mark for intermediate if phenolic O– is missing **curly arrow** must start from, **OR** be traced back to, **any part of** C-H bond and go inside the 'hexagon'  **<u>Examiner's Comments</u>** Candidates who answered this question well had clear mechanisms. Too often positioning of curly arrows was ambiguous.
		ii	OH^- : base ✓ CO_2: electrophile **OR** electron pair acceptor ✓	2 (AO2.1×2)	**ALLOW** alkali **IGNORE** 'nucleophile', 'donates electron pair' **IGNORE** lone pair acceptor (*No lone pair involved*)
		iii	 One ester link in organic product ✓ Correct structure of organic product ✓ Correct equation **AND** balanced ✓	3 (AO3.1) (AO3.2) (AO2.6)	**<u>Examiner's Comments</u>** Candidates who found this question difficult often did not recognise the functional groups present in the reacting molecule. Those that identified an esterification reaction often then did not balance the equation.
			Total	**11**	
45	a	i	Butan-2-ol	1 (AO1.2)	
		ii	$(CH_3)_2CHCH_2OH + 2[O] \rightarrow (CH_3)_2CHCOOH + H_2O$ **B** as reactant: $(CH_2)_2CHCH_2OH$ ✓ $(CH_3)_2CHCOOH$ as product ✓	3 (AO2.5 × 2) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous If structure of **B** is a different primary or

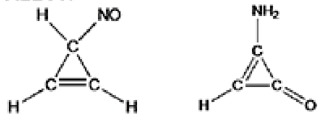
			Correct equation with 2[O] and H_2O ✓		secondary alcohol, **ALLOW ECF** for product and equation
	b		 Correct skeletal formulae for organic compounds ✓ Complete balanced equation ✓	2 (AO2.5 × 2)	Skeletal formulae needed for 1st marking point. For complete balanced equation, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous, e.g. $(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$
			Total	**6**	
46	a		$3KClO_4 + 8Al \rightarrow 3KCl + 4Al_2O_3$ ✓	1 AO2.6	**ALLOW** multiples
	b		**Plan** Mix (solution of) halogen and (solution of) halide ✓ **Observation with chlorine** bromide → orange/yellow ✓ **Observation with bromine** iodide → violet/purple/pink ✓ **Observation with iodine** No colour change/no reaction ✓ **Equation** $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ **OR** $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ **OR** $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ ✓ **Reactivity trend** $Cl_2 > Br_2 > I_2$ /decreases down the group ✓	5 max AO3.3 AO2.7 AO2.7 AO2.7 AO2.6 AO1.1	**IGNORE** additions of halogen to same halide e.g. Chlorine to chloride. **ALLOW** within text if it is clear that halogen is added to halide Check observations in a presented table. **ALLOW** multiples, e.g. $\frac{1}{2}Cl_2 + Br^- \rightarrow \frac{1}{2}Br_2 + Cl^-$
			Total	**6**	
47		i	Alcohol **C**:  ✓ Reagent **AND** product: NaOH **AND** NaBr **OR** KOH **AND** KBr **OR** OH^- **AND** Br^- ✓	2 AO2.5×2	**ALLOW** Reagent: H^2O/water **AND** Product: HBr
		ii		2 AO3.3×2	**For condenser label, ALLOW** 'condenser' **OR** water in **AND** water out (May be implied by connection to tap and sink).

			 **1st mark:** **Labelled condenser** above a flask ✓ **2nd mark:** *Only available if 1st mark has been awarded* Flask **AND** heat labelled ✓		
			Total	**4**	
48			$3C_3H_6O \rightarrow C_9H_{12} + 3H_2O$ molecular formulae of C_3H_6O **AND** C_9H_{12} ✓ H_2O as by-product ✓ correct balanced equation ✓	3 (AO2.6) (AO2.5) (AO2.6)	
			Total	**2**	
49	a	i	**Reagents** $K_2Cr_2O_7$ **AND** acid **AND** reflux ✓ **Equation** $HO(CH_2)_4OH + 4[O] \rightarrow HOOC(CH_2)_2COOH + 2H_2O$ [O] **AND** H_2O ✓ Correctly balanced equation ✓	3 (AO1.1) (AO2.5) (AO2.6)	**ALLOW** $Na_2Cr_2O_7$ **OR** $Cr_2O_7^{2-}$ **ALLOW** H_2SO_4 **OR** HCl **OR** H^+ **ALLOW** words. e.g. 'acidified dichromate' **ALLOW** a small slip in formula for dichromate e.g KCr_2O_7, **<u>Examiner's Comments</u>** Many candidates did not correctly balance this equation or missed water as a product entirely.
		ii	 **OR**  Diagram showing correct dipole charges on each end of one hydrogen bond between a water molecule and a diacid ✓ Hydrogen bond between one lone pair on O atom in one of the molecules and	2 (AO2.1×2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** δ+ on H atoms of CH_2 group **ALLOW** H-bond for hydrogen bond **ALLOW** H bond between C=O and H_2O, i.e. 

			the H atom of another **AND** Hydrogen bonding stated or labelled on diagram		**IF** diagram is not labelled, **ALLOW** hydrogen bond/H bond from text **<u>Examiner's Comments</u>** Candidates who answered this question well had clear, labelled diagrams. Too often, labels, dipoles and lone pairs were missing.
	b	i	 Ester link (must be displayed) ✓ Rest of structure ✓	2 (AO1.2) (AO2.5)	**ALLOW** the 'O' or C=O at either end, e.g.  **IGNORE** brackets **IGNORE** *n* End bonds' **MUST** be shown (solid or dotted) **DO NOT ALLOW** more than one repeat unit
		ii	the ester/ ester bond/ ester group /polyester can be broken down ✓ **OR** It can be hydrolysed ✓	1 (AO3.2)	**IGNORE** references to photodegradable 'Bond breaks' is not sufficient – no reference to ester bond
		iii	 $SOCl_2$ in equation ✓ Structure of diacyl dichloride ✓ Complete balanced equation ✓	3 (AO1.1) (AO1.2) (AO2.6)	**ALLOW** alternative approach using PCl_5 or PCl_3
			Total	**11**	
50			**Interpretation of Results** Orange contains bromine **AND** no reaction **AND** violet contains iodine ✓ **Ionic equation** $Br_2 + 2I^- \rightarrow 2Br^- + I_2$ ✓ **Reactivity (down the group)** Reactivity decreases **AND** oxidising power decreases **OR** gains electrons less easily **OR** forms negative ion/1– ion less easily **OR** less energy released when	5 (AO 2.3× 1) (AO 2.6×1) (AO 1.1×3)	Results can be interpreted anywhere in answer. **ALLOW** multiples, e.g. $\frac{1}{2}Br_2 + I^- \rightarrow Br^- + \frac{1}{2}I^2$ **IGNORE** other halogen/halide equations **IGNORE** state symbols **ALLOW** ORA **DO NOT ALLOW** idea of losing electrons/ionisation energy **IGNORE** chlorine is the most electronegative

51			electron **gained** ✓ **OR** more negative electron affinity **Size/shells/shielding (down the group)** Greater atomic radius **OR** more shells **OR** more shielding ✓ **Attraction (down the group)** Less **nuclear** attraction down the group ✓		**IGNORE** explanations in terms of displacement **<u>Examiner's Comments</u>** This question required the candidate to explain the reactivity of the halogens given experimental observations. Higher-attaining candidates were able to explain the observations with ionic equations and explain the reactivity in terms of gaining electrons. Some candidates did not associate the colour with the halogen and linked it with the halide ion, but then did explain the trend in reactivity due to the ability to gain electrons. Lower-attaining candidates explained the reaction in terms of displacement (which was ignored) and they did not proceed with ionic equations or describe the ability to gain electrons. **Misconception** Some candidates linked the ability to gain electrons to ionisation energy rather than electron affinity. The colour of the organic layer was also associated with the halide ion rather than the halogen. **OCR support** Further guidance can be found in the AS Level delivery guide 'Theme: Patterns' (Group 2 and Group 17): https:/www.ocr.org.uk/Images/231740-patterns.pdf
			Total	**5**	
51			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** All three tests are covered in detail, with at least **six** of **B** to **H** identified correctly and equations mostly correct. *There is a well-developed line of*	6 (AO 3.3×3) (AO 3.4×3)	**Indicative scientific points may include:** **Identification of unknowns** Can be identified within labelled equation. **B** is $FeSO_4$ **OR** Iron(II) sulfate • Test 1: Fe^{2+} present • Test 2: SO_4^{2-} present

			reasoning which is clear and logically structured. The information presented is relevant and substantiated. **Level 2 (3–4 marks)** All three tests are covered with at least **four** of **B** to **H** identified correctly. Some attempt at writing equations, but with several omissions or incorrect formulae. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Only two tests covered with at least **two** of **B** to **H** identified correctly, and little attempt at writing equations. *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.*		**D** is $Fe(OH)_2$ **OR** $[Fe(H_2O)_4(OH)_2]$ **OR** iron(II) hydroxide **G** is $BaSO_4$ OR barium sulfate **C** is $CrCl_3$ **OR** chromium(III) chloride • Test 1: Cr^{3+} present • Test 3: Cl^- present **E** is $Cr(OH)_3$ **OR** $[Cr(H_2O)_3(OH)_3]$ **OR** chromium(III) hydroxide **F** is $[Cr(NH_3)_6]^{3+}$ **H** is silver chloride OR $AgCl$ **Equations** **D**: $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ **OR** $Fe^{2+} + 2OH_- \rightarrow Fe(OH)_2$ **OR** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow [Fe(H_2O)_4(OH)_2] + 2H_2O$ **OR** $[Fe(H_2O)6]^{2+} + 2NH_3 \rightarrow [Fe(H_2O)_4(OH)_2] + 2NH_4^+$ **OR** $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(OH)_2 + 4H_2O + 2NH_4^+$ **E**: $[Cr(H_2O)6]^{3+} + 3OH^- \rightarrow Cr(OH)_3 + 6H_2O$ **OR** $Cr^{3+} + 3OH^- \rightarrow Cr(OH)_3$ **OR** $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow [Cr(H_2O)_3(OH)_3] + 3H_2O$ **OR** $[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow [Cr(H_2O)_3(OH)_3] + 3NH_4^+$ **OR** $[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow Cr(OH)_3 + 3H_2O + 3NH_4^+$ **F**: $[Cr(H_2O)_6]^{3+} + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$ **OR** $Cr(OH)_3 + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3OH^-$ **OR** $[Cr(H_2O)_3(OH)_3] + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3H_2O + 3OH^-$ **G**: $Ba^{2+} + SO4^{2-} \rightarrow BaSO_4$ **H**: $Ag^+ + Cl^- \rightarrow AgCl$
			Total	**6**	
52			**D**	1 (AO 1.2)	**ALLOW** 1 in the answer box
			Total	**1**	
53				2 (AO 3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

			Organic product and **water** marked **independently**. *1st mark* correct organic product **OR** water **IGNORE** balancing numbers *2nd mark* **BOTH** products **AND** correctly balanced.		**ALLOW**  **NOTE**: For **ECF**, any structure must have correct number of bonds to C, H, O and N **DO NOT ALLOW** structure of dimer *Question states molecular formula = C_3H_3NO* **<u>Examiner's Comments</u>** Candidates were supplied with information about an unfamiliar reaction of an amino acid and asked to predict a possible equation. Many candidates suggested H_2O as one product, being the difference in the formula of the amino acid and the C_3H_3NO cyclic organic product. Any cyclic structure of C_3H_3NO that met the bonding rules for C, H, N and O was credited. Examples included a 4-membered ring lactam and substituted cyclopropenes. A significant number of candidates showed an equation for the reaction of two molecules of the amino acid to form 2 H_2O and a cyclic dipeptide. Although chemically feasible, the dipeptide could not be credited because the molecular formula was C_3H_3NO in the question. This error could have been avoided if the information in the question had been used.
			Total	**2**	
54		i	**Overall equation AND state symbols:** **M**(s) + 2HCl(aq) → **M**Cl_2(aq) + H_2(g) ✓	3 (AO 2.6×3)	**All 3 marks are independent.** **IGNORE** charges/oxidation numbers shown around overall *equation*. *Treat as rough working* **ALLOW** overall equation shown with some or all ions that are present e.g. (**<u>with state symbols</u>**) $M + 2H^+ \rightarrow M^{2+} + H_2$ $M + 2HCl \rightarrow M^{2+} + 2Cl^- + H_2$ $M + 2H^+ + 2Cl^- \rightarrow M^{2+} + 2Cl^- + H_2$ In half equations, **IGNORE** state symbols even is wrong BUT half equations MUST only have species that change. For charges on half equations,

			STATE SYMBOLS required in overall equation ONLY **Half equations:** Oxidation **M** → $\mathbf{M^{2+}}$ + $2e^-$ ✓ Reduction $2H^+ + 2e^- \rightarrow H_2$ **OR** $H^+ + e^- \rightarrow \frac{1}{2}H_2$ ✓		**ALLOW** M^{+2} for M^{2+} **OR** H^{+1} for H^+ **ALLOW M** – $2e^-$ → $\mathbf{M^{2+}}$ If **BOTH** half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations **<u>Examiner's Comments</u>** This question required candidates to write an overall equation and half equations for oxidation and reduction. Many candidates made errors within one or more equations. The overall equation was often written without state symbols, despite the question instruction 'with state symbols'. The oxidation half equation was more likely to be correct than the reduction half equation, which often used Cl instead of H^+. When H^+ was used, the half equation was often unbalanced or electrons had been omitted. It is recommended that candidates carefully use the chemical information in the question.
		ii	Bubbles/effervescence/fizzing stops ✓ **M**/metal/solid has disappeared/dissolved ✓	2 (AO 3.3×2)	Responses must imply that all fizzing has stopped and that all the solid has dissolved **i.e.** 'metal disappears' is not quite enough. 'All the metal disappears' is enough **IGNORE** constant mass **IGNORE** no increase in temperature **<u>Examiner's Comments</u>** Most candidates identified that all the metal would have reacted when it had all disappeared and that gas bubbles from the reaction would have stopped. Some responses did not emphasise that these observations would have stopped and this prevented credit being given.
		iii	$H^+ + OH^- \rightarrow H_2O$ ✓	1 (AO 2.5)	**ALLOW** multiples e.g. $2H^+ + 2OH^- \rightarrow 2H_2O$ **IGNORE** state symbols, even if wrong **<u>Examiner's Comments</u>** The ionic equation for neutralisation of an acid with an alkali was well known and

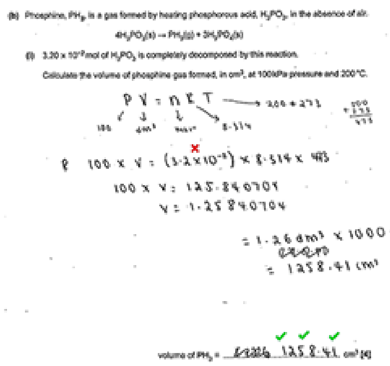
					this question was answered correctly by most candidates.
		iv	**Mean titre 1 mark** $= \frac{(27.30 + 27.20)}{2} = 27.25$ (cm^3) ✓ **Analysis of results 5 marks** $n(NaOH) = 27.25 \times \frac{0.320}{1000} = 8.72 \times 10^{-3}$ (mol) ✓ n(HC*l*) in 25.0 cm^3 = n(NaOH) n(HCl) in 250 cm^3 $= 8.72 \times 10^{-3} \times 10 = 8.72 \times 10^{-2}$ (mol) ✓ n(HC*l*) that reacted with **M** $= 0.210 - 8.72 \times 10^{-2} = 0.1228$ (mol) ✓ n(**M**) that reacted $= \frac{0.1228}{2} = 0.0614$ (mol) ✓ A_r of M $= \frac{6.90}{0.0614} = 112.4$ **AND M** = cadmium/Cd ✓ **COMMON ERRORS:** Mean of 27.35 (use of all 3 titres) → 8.752×10^{-3} → 8.752×10^{-2} → 0.12248 → 0.06124 → 112.7 **AND** Cd: *5 marks* *No ÷2 to obtain n(M)* → 56.2 **AND** Fe (from 27.25) *5 marks* → 56.3 **AND** Fe (from 27.35) *4 marks* *No subtraction from 0.210* A_r of M $= \frac{6.90}{0.0614} = 112.4$ **AND M** = cadmium/Cd ✓ → 158.2 to 158.3 **AND** Tb *5 marks* No ×10 to *obtain n(HCl) in 250 cm^3* *5 marks* $0.210 - 8.72 \times 10^{-3} = 0.20128$ **OR** 0.201 *n(M)* = 0.20128/2 = 0.10064 Ar = 6.90/0.10064 = 68.56 → Zn *No ×10 and no ÷ 2* *4 marks* $0.210 - 8.72 \times 10^{-3} = 0.20128$ Ar = 6.9/0.20128 = 34.28 → Ca *Omitting initial titration calculation* *Zero marks* 0.210/2 = 0.105 → 6.9/0.105 = 65.71 → Zn	6 (AO 2.8×5) (AO 3.2)	***FULL ANNOTATIONS MUST BE USED*** --- **Common error:** Incorrect mean from all 3 titres = 27.35 cm^3 **Use ECF throughout** Intermediate values for working to **at least 3 SF**. **TAKE CARE**: Value written down may be truncated calculator value. Depending on rounding, either can be credited. **ALLOW** 0.123 (mol) i.e. 3SF **ALLOW** 0.0615 (mol) **IF** 0.1228 rounded to 0.123 **ALLOW** 112.2 from 0.0615 **AND** Cd **ALLOW** A_r to nearest whole number **ALLOW ECF** for metal closest to calculated A_r **DO NOT ALLOW** Ga **OR** Sc (Form 3+ ions only) **<u>Examiner's Comments</u>** Candidates were presented with information about a back titration, a technique that they would be unlikely to have encountered during their course. The question stem to (iv) suggested a three-step strategy. Many candidates followed this guidance and were credited with many of the available marks. Marks were given for a correct method (by error carried forward) even if there was an error or omission in the multi-step calculation. This emphasises the importance of clear working. Most candidates determined the correct mean titre of 27.25 cm^3. A few candidates did take the mean of all three titres rather than the closest. Most calculated that 8.72×10^{-3} mol of NaOH reacted with the same number of moles of HC*l* in the

					titration and then scaled up the HC*l* by a factor of 10 to 8.72 × 10^{-2} mol in the 250 cm^3 volumetric flask. These steps are standard for many titration calculations and gave a route to three of the six available marks. The more difficult back titration steps then followed and the higher-attaining candidates recognised the need to subtract this amount of HC*l* from the original amount of HC*l* used to react with metal M. These candidates then divide this value by two to find the moles of M that reacted (from the 1 : 2 stoichiometry of M : HC*l*). The correct calculation then gave a relative atomic mass of M as 112 and its identity as cadmium. It was common for candidates to omit the division by two and to arrive at a relative atomic mass of 56 for iron. The mark scheme shows the variety of metals that candidates identified from their calculations, the errors made, and the error carried forward marks that resulted. Many lower-attaining candidates did not follow the 3 steps in the stem, using only the original amount of HCl and ignoring the titration. This approach was not credited with marks. A large range of marks was seen, and the question discriminated extremely well.
			Total	**12**	
55		i	$Al_2Se_3 + 6H_2O \rightarrow 2Al(OH)3 + 3H_2Se$	1 (AO2.6×1)	**Examiner's Comments** This was dependent on candidates' ability to give correct formula of aluminium hydroxide, $Al(OH)_3$. Writing correct formulae is an important skill in chemistry, which should be practised regularly in different topics to help candidates master the skill.
		ii	H_2O has hydrogen/H-bonds (between molecules) ✓ H_2Se has induced dipole(-dipole) interactions **OR** London forces ✓ H-bonds are stronger (than other intermolecular forces) **OR** more energy needed to overcome H-bonds ✓	3 (AO1.1×2) (AO2.1×1)	**ALLOW** permanent dipole-dipole interactions **Examiner's Comments** Most candidates were able to recognise that water had the higher boiling point due to hydrogen bonding. However, it was evident in a number of responses that they were unclear that this is an example of an intermolecular force and doesn't just refer to the covalent bond formed between O and H.

					Most avoided discussing the intermolecular forces present in H_2Se even although both London forces and permanent dipole-dipole interactions were accepted as they may not have come across this specific example and had not been given electronegativity data.
			Total	4	
56		i	$(1s^2)2s^22p^63s^23p^63d^{10}4s^24p^5$ ✓ Look carefully at $1s^22s^22p^63s^23p^6$ – there may be a mistake	1 (AO1.2)	**ALLOW** 3d after $4s^2$, e.g. $1s^22s^22p^63s^23p^64s^23d^{10}4p^5$ **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_23D_1$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ **IGNORE** $1s_2$ repeated __**Examiner's Comments**__ Candidates answered this part well, showing good knowledge and understanding of electron configuration. When incorrect, it was usually errors with the number of electrons in the 3d and 4p subshells.
		ii	$P_4 + 6Br_2 \rightarrow 4PBr_3$ ✓	2 (AO2.4)	**ALLOW** multiples __**Examiner's Comments**__ Most candidates were able to construct a correct balanced equation for this unfamiliar equation. The commonest error was use of Br instead of Br_2 in the equation.
			Total	2	
57			**Route 1** *Reactant:* Add water (to Ba) **OR** H_2O in equation ✓ *Balanced equation:* $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$ ✓ **Route 2**	4 (AO3.3) (AO2.6) (AO3.3) (AO3.3)	**ALLOW** multiples in equations Balanced equation automatically collects 2 marks for Route 1 **ALLOW** 1 mark for **BOTH** reactants in route 2: i.e. React with O_2 **AND** then with H_2O **NOTE** 3 correct balanced equations → 4 marks __**Examiner's Comments**__

			Balanced equation with O_2 $2Ba + O_2 \rightarrow 2BaO$ ✓ *Balanced equation with H_2O* $BaO + H_2O \rightarrow Ba(OH)_2$ ✓		Many candidates were able to calculate the amount of HNO_3 in the titration as 4.28×10^{-3} mol. Most candidates were credited for the amount of $Ba(OH)_2$ as 2.14×10^{-3} mol, half the calculated amount of HNO_3. Candidates then need to scale up this value by 1000/25 to obtain the concentration as 0.0856 mol dm^{-3}. All intermediate calculations gave values to 3 significant figures. Discrimination was extremely good, but about a third of candidates did not receive any marks. Candidates should be encouraged to practise stock titration calculations as part of their preparation for the examinations. Candidates should show clear working so that credit can be given for such responses by applying error carried forward. Many candidates produced largely unreferenced numbers.
			Total	**4**	
58			**C**	1 (AO1.2)	**ALLOW** 4 **<u>Examiner's Comments</u>** Candidates found this question difficult, with the nitric acid N atoms being split between two products, $Cu(NO_3)_2$ and NO_2. B proved to be the biggest distractor from the correct response of C, probably the result of miscounting the N atoms.
			Total	**1**	
59			**C**	1 (AO1.2)	**<u>Examiner's Comments</u>** Candidates are expected to know the charges on silver and carbonate ions. However, a number of candidates responded with A: $AgCO_3$, rather than C: Ag_2CO_3.
			Total	**1**	
60			B	1 (AO 2.8)	**<u>Examiner's Comments</u>** This was a challenging question, the correct answer being B. Candidates had to know the correct formula for sodium carbonate in order to deduce the 2:1 molar ratio of HCl to Na_2CO_3 and to calculate its Mr (106). Option D was arrived at by assuming the molar ratio was 1:1, option A by incorrectly thinking the

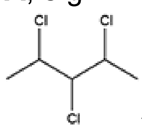
					formula was $NaCO_3$, and option C by making both of these mistakes.
			Total	**1**	
61		i	**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 315 (cm3) award 4 marks** --- **Amount of PH_3** $n(PH_3) = \frac{3.20 \times 10^{-2}}{4}$ OR $8(.00) \times 10^{-3}$ (mol) ✓ **Unit conversions** *p* conversion → Pa = 100×10^3 (Pa) **AND** *T* conversion → K = 473 (K) ✓ **Evidence of use of rearranged gas equation** **OR** $V = \frac{nRT}{p}$ **OR** V OR $V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 473}{100 \times 10^3}$ **OR** $V = 3.15 \times 10^{-4}$ ✓ *Calculator:* = 3.1460176×10^{-4} ***V* conversion of m^3 → cm^3 ✓** $V = 3.15 \times 10^{-4} \times 10^6 = 315\ cm^3$ ✓ *Calculator from unrounded cm^3*: 314.60176 cm^3 ***Requires 3 OR MORE SF, correctly rounded*** ***ALLOW use of R = 8.31 → 314.4504 → 314 to 3SF***	**4**	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW ECF** throughout --- **Common Errors (3 marks)** ***Use of n(H3PO4) = 3.20×10^{-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 cm^3 (1260 to 3 SF) ***No temperature conversion from °C to K*** $V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 200}{100 \times 10^3} \times 10^6$ = 133 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 cm^3 ***No volume conversion from m^3 to cm^3*** $V = 3.15 \times 10^{-4}$ **IGNORE** use of 24/24000 for molar volume e.g. $3.2(0) \times 10^{-3} \times 24000 = 768$ scores zero $8(.00) \times 10^{-3} \times 24000 = 292$ scores 1st mark only <u>**Examiner's Comments**</u> 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. Answer = 315 cm^3 **Exemplar 3**  (b) Phosphine, PH_3, is a gas formed by heating phosphorous acid, H_3PO_3, in the absence of air. $4H_3PO_3(s) \rightarrow PH_3(g) + 3H_3PO_4(s)$ (i) 3.20×10^{-3} mol of H_3PO_3 is completely decomposed by this reaction. Calculate the volume of phosphine gas formed, in cm^3, at 100kPa pressure and 200°C. PV = nRT → 200 + 273 100 × V = (3.2×10⁻³) × 8.314 × 473 100 × V = 125.840701 V = 1.25840704 = 1.26 dm³ × 1000 = 1258.41 cm³ volume of PH_3 = 1258.41 cm³ [4]
		ii	$4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓	1	**ALLOW** multiples **<u>Examiner's Comments</u>** Most candidates were able to write a correctly balanced equation for this reaction.
			Total	**5**	
62	a		**Structural isomers:** *1 mark* Different structural formulae AND same molecular formula ✓ **Common molecular formula:** *1 mark* C_5H_{12} for all 3 hydrocarbons ✓	5	For 'structural': **ALLOW** different structure **OR** different displayed/ skeletal formula **DO NOT ALLOW** any reference to spatial/space/3D Same formula is **not** sufficient (no 'molecular') Different arrangement of atoms is **not** sufficient (no 'structure'/'structural') **ALLOW** 5 carbons and 12 hydrogens **ALLOW** for 2 marks: Different structural formulae **AND** same molecular formula ✓ of C_5H_{12} ✓ **Comparisons** needed throughout

	b		**Boiling point and branching:** *1 mark* Boiling point decreases with more branching **OR** more methyl/alkyl groups/side chains **OR** shorter carbon chain ✓ **Branching and London forces:** *1 mark* *Could be seen anywhere within response* More branching gives less (surface) contact **AND** fewer/weaker London forces ✓ **Energy and intermolecular forces:** *1 mark* Less energy to break London forces/ intermolecular forces/intermolecular bonds/ ✓		**ORA** throughout **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 **ALLOW** induced dipole(−dipole) interactions **IGNORE** van der Waals'/vdw forces **ALLOW** SA for surface area **ALLOW** 'harder to overcome intermolecular forces **ALLOW** more energy to separate the molecules **IGNORE** just 'bonds' ***intermolecular/London forces*** *required* **Examiner's Comments** 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.
	b		Enter text here.	Enter text here.	Enter text here.
		i	Radical substitution ✓	**1**	**ALLOW** Free radical substitution **Examiner's Comments**

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>Most candidates identified this reaction as radical substitution.</td></tr>
<tr><td></td><td></td><td>ii</td><td><table><tr><th>A</th><th>B</th></tr><tr><td>3 ✓</td><td>4 ✓</td></tr></table></td><td>2</td><td><u>Examiner’s Comments</u>

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.</td></tr>
<tr><td></td><td></td><td>iii</td><td>Structure of D

Structure of a trichloro isomer of A, e.g.
 ✓
ALLOW any trichloro isomer of A
CHECK carefully

Equation

$C_5H_{12} + 3Cl_2 \rightarrow C_5H_9Cl_3 + 3HCl$ ✓
Molecular formulae required

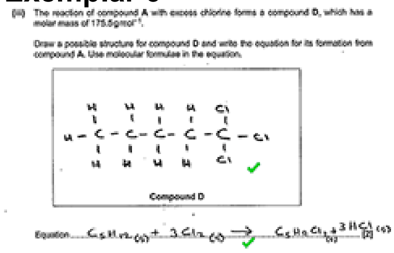
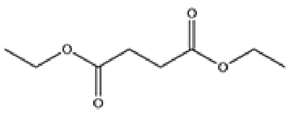
NO ECF from incorrect structure of D</td><td>2</td><td>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)

IGNORE molecular formula

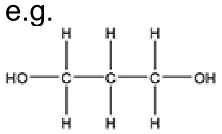
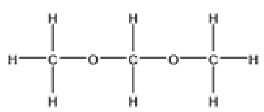
ALLOW multiples,
e.g. $2C_5H_{12} + 6Cl_2 \rightarrow 2C_5H_9Cl_3 + 6HCl$

<u>Examiner’s Comments</u>

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 H2 as the second product rather than HCl.</td></tr>
</table>

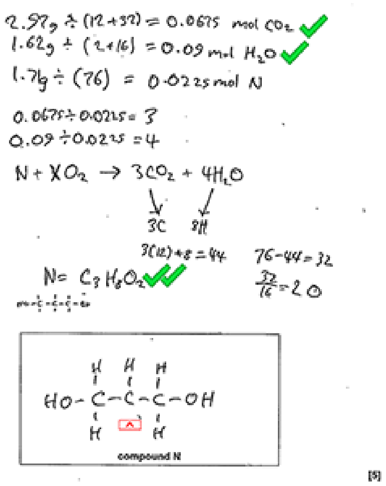
					Exemplar 6 
			Total	**10**	
63			**C**	**1**	**<u>Examiner's Comments</u>** Nearly all candidates responded with the correct response of C.
			Total	**1**	
64		i	Titration ✓	1	**IGNORE** type of titration **<u>Examiner's Comments</u>** Candidates found this part difficult and only higher ability candidates identified that a titration could easily determine the concentration of succinic acid. 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.
		ii	$(CH_2COOH)_2 + 2C_2H_5OH \rightleftharpoons (CH_2COOC_2H_5)_2 + 2H_2O$ ✓	1	**ALLOW** → instead of ⇌ sign **ALLOW** molecular formulae or hybrid formulae *Structures provided on QP* e.g. $C_4H_6O_4 + 2C_2H_6O \rightleftharpoons C_8H_{14}O_4 + 2H_2O$ **<u>Examiner's Comments</u>** Candidates were required to derive the equation from which the supplied K_c expression had been written. Overall, this part was answered well but some candidates struggled with the brackets or used CH_2COOH_2 for succinic acid.
		iii	 ✓	1	**IGNORE** displayed formulae **<u>Examiner's Comments</u>** 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. Even when incorrect, most attempted answers were skeletal formulae.
		iv	Volume cancels **OR** Same number of moles on each side of equation ✓	1	**ALLOW** units cancel **ALLOW** (sum of) balancing numbers/coefficients on each side of equation are the same **OR** same number of (moles of) reactants and products **IGNORE** volume is the same; K_c has no units **<u>Examiner's Comments</u>** 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. This challenging part discriminated very well. The best responses showed the units as n/V in the expression and showed that the volumes cancel.
		v	**Moles of equilibrium products** ***1 mark*** $n((CH_2COOC_2H_5)_2)$ = 0.0300 (mol) **AND** $n(H_2O)$ = 0.0600 (mol) ✓ **Moles of C_2H_5OH** ***1 mark*** $n(\mathbf{C_2H_5OH})$ = 0.150 − 0.060 = 0.0900 (mol) ✓ **K_c calculated** ***1 mark*** $= \frac{0.03 \times 0.06^2}{0.02 \times 0.09^2}$ = 0.667 OR 0.67 ✓ **NOTE**: 0.02 must be used for *n*(succinic acid)	3	**ALLOW ECF** **ALLOW** 0.66, 0.666, etc. (**2 SF** and more) *Treated as meaning 0.6 recurring* **ALLOW** 2/3 **IGNORE** any units **<u>Examiner's Comments</u>**

					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. 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.
			Total	**7**	
65	a	i	$n(CO_2)$ = 2.97/44 = 0.0675 (mol) ✓ $n(H_2O)$ = 1.62/18 = 0.0900 (mol) ✓ **Ratio of C : H** 3 : 8 ✓ **Molecular formula** $C_3H_8O_2$ ✓ **Structure** any correct structure of $C_3H_8O_2$ ✓ e.g.  **OR**  etc	**5**	Consult your team leader if an alternative creditworthy approach is seen **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 **DO NOT ALLOW** an incorrect molecular formula Mark independently from molecular formula but structure **MUST** contain 3C, 8H and 2O **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any vertical bond to the OH group e.g. **ALLOW**  **OR**  **DO NOT ALLOW** OH– **<u>Examiner's Comments</u>** 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 frequency.

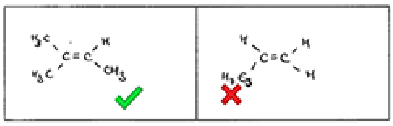
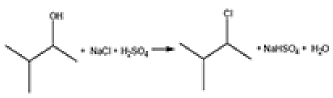
Exemplar 11

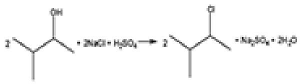
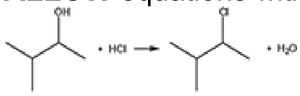
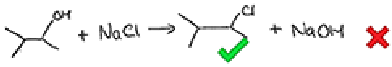
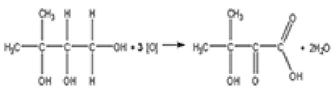
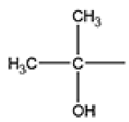
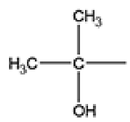


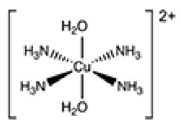
This response is logically presented with clear working demonstrating the candidate's approach. In the first part the candidate determines the amount, in moles, of carbon dioxide and water produced. This response uses the number of moles of **N** to deuce the molar ratio of CO_2 to H_2O. Other candidates 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 to future candidates. The working on the right hand side shows how the amount of O in compound **N** is determined.

					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.
		ii	 Carbonyl compound identified as propanone ✓ Rest of equation ✓	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **<u>Examiner's Comments</u>** 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.
	b		$C_7H_{16} + 7^1/_2O_2 \rightarrow 7CO + 8H_2O$ **OR** $C_7H_{16} + 4O_2 \rightarrow 7C + 8H_2O$ ✓	**1**	**ALLOW** multiples **IGNORE** state symbols **ALLOW** equations for incomplete combustion that give CO and/or C with CO_2 e.g $C_7H_{16} + 9O_2 \rightarrow 4CO + 3CO_2 + 8H_2O$ $C_7H_{16} + 6O_2 \rightarrow 4CO + 3C + 8H_2O$ **<u>Examiner's Comments</u>** The majority of candidates were able to provide a correct equation for the incomplete combustion of heptane.
			Total	**8**	
66	a	i	3-methylbutan-2-ol ✓	**1**	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylbutane-2-ol **DO NOT ALLOW** 2-methylbutan-3-ol **OR** 3-methylbut-2-ol **OR** 3-methbutan-2-ol **OR** 3-methybutan-2-ol **OR** 3-methlybutan-2-ol **<u>Examiner's Comments</u>** The majority of candidates were able to correctly name alcohol A as 3-methylbutan-2-ol. A significant number of responses used incorrect numbering and suggested 2-methylbutan-3-ol as the name.

		ii	$(CH_3)_2CHCHOHCH_3$ ✓	**1**	**ALLOW** brackets around OH e.g. $(CH_3)_2CHCH(OH)CH_3$ **ALLOW** any unambiguous structural formula e.g. $CH_3CH(CH_3)CHOHCH_3$ $CH_3CH(CH_3)CH(CH_3)OH$ **<u>Examiner's Comments</u>** Most candidates were able to show a correct structural formula of alcohol A.
		iii	One mark for each correct structure. 	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** in either order **<u>Examiner's Comments</u>** Many candidates correctly identified the two alkenes formed as 2-methylbut-2-ene and 3-methybut-1-ene. Stronger responses used skeletal formula to show the structures clearly. Some candidates preferred to use chemical symbols to represent the atoms present and although this approach is valid, lower ability responses did not show sufficient detail as demonstrated in Exemplar 1. **Exemplar 1**  In this response the alkene 2-methylbut-2-ene has been correctly identified and one mark credited. However, the attempt to show 3-methylbut-1-ene does not score. This is because C_3H_7 has been used instead of $CH(CH_3)_2$. Candidates should be encouraged to show every carbon atom when drawing a structure as the use of ambiguous formulae is not sufficient to gain credit.
		iv	 Correct haloalkane ✓	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ for H_2SO_4 **ALLOW** equations forming Na_2SO_4

			Correctly balanced equation ✓		 **ALLOW** equations with HCl  **DO NOT ALLOW** equations that form NaOH **<u>Examiner's Comments</u>** This question proved difficult for candidates. Although many candidates were able to identify the correct organic product, only the higher ability candidates were able to construct an appropriate balanced equation. A common error was to omit the role of the acid; this is shown in Exemplar 2 below. Lower ability candidates appeared not to recognise this reaction and suggested an alkoxide salt, rather than a haloalkane as the organic product. **Exemplar 2**  This type of response was seen frequently by examiners. The candidate has drawn the correct structure of the haloalkane formed and scores the first mark. However, the response fails to recognise that the reaction occurs under acidic conditions and omits the sulfuric acid from the equation.
	b		 Correct organic product ✓ Rest of equation ✓	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** any vertical bond to the tertiary OH group e.g. **ALLOW**  **OR**  **<u>Examiner's Comments</u>** This question required candidates to apply

					their knowledge of the oxidation of alcohols to complete the equation for the complete oxidation of compound B. This question discriminated well. Many candidates correctly identified the organic product but only the higher ability candidates could complete the equation. A common error was to omit water as a product of the reaction.
			Total	**8**	
67			*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** All three reactions are covered in detail with **C**, **D**, **E** and **F** identified with clear explanations. *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.* **Level 2 (3–4 marks)** All three reactions are covered but explanations may be incomplete **OR** Two reactions are explained in detail. *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.* **Level 1 (1–2 marks)** 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.	**6**	**Indicative scientific points may include:** **REACTION 1 ($CuSO_4$/NH_3)** ***Product*** C : $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ***Equation*** $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ***Structure of trans stereoisomer***  Correct connectivity **REACTION 2 (Cu_2O/H_2SO_4)** ***Products*** **D** : $CuSO_4$ **OR** $[Cu(H_2O)_6]^{2+}$ **E**: Cu **Equation** $Cu_2O + H_2SO_4 \rightarrow CuSO_4 + Cu + H_2O$ ***Oxidation numbers*** Cu(+1) → Cu(+2) + Cu(0) **REACTION 3 (CuO/HNO_3)** ***Equation*** $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$ ***Molar ratios***

$$\begin{array}{cccc} Cu & : H & : N & : O \end{array}$$

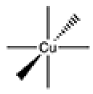
$$= \frac{26.29}{63.5} : \frac{2.49}{1.0} : \frac{11.59}{14.0} : \frac{59.63}{16.0}$$

Formula of F

$CuH_6N_2O_9$
F: $Cu(NO_3)^2{\bullet}3H_2O$ (**OR** $Cu(NO_3)_2(H_2O)_3$)

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:


<u>Examiner’s Comments</u>

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

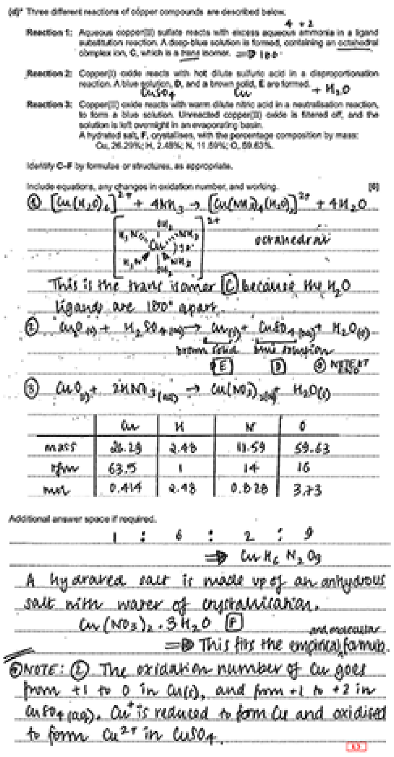
Most candidates recognised **C** as the ammoniacal copper(II) ion but the formula was frequently incorrect and correct attempts at a ligand substitution equation from $[Cu(H_2O)_6]^{2+}$ was rarely seen. Diagrams showing the *trans* isomer were attempted but often of poor quality due to incorrect linking.

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. $Cu(OH)_2(s)$ was a common incorrect identification of **E**. Only the best responses described the oxidation number changes which made this a disproportionation reaction.

F was identified by a percentage by mass calculation to determine an empirical formula and then by deduction to produce $Cu(NO_3)_2.3H_2O$. Having done this, many candidates did not give the relatively simple equation for reaction **3** between copper(II) oxide and dilute nitric acid.

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>

Exemplar 2



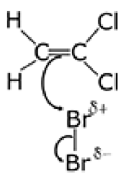
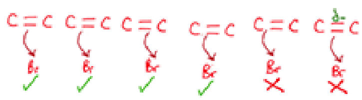
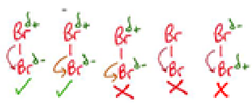
This exemplifies how considered structuring of candidate responses can enhance their clarity. The clear labelling of C-F in the response, along with numbering which corresponds to the reactions in the question stem, make the candidate’s line of reasoning easy to follow. The underlining and annotations in the question stem show good practice in picking out and interpreting key information.

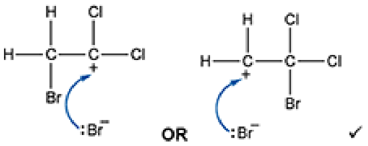
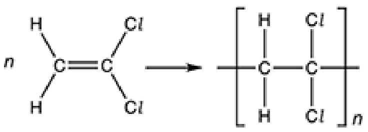
</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>6</td><td></td></tr>
<tr><td>68</td><td></td><td></td><td>C</td><td>1 (AO 1.2)</td><td>

<u>**Examiner’s Comments**</u>

Nearly all candidates were able to determine the most likely formula.

</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
</table>

69			**D**	**1 (AO 2.3)**	**Examiner's Comments** Most candidates knew that the formula given in D was incorrect.
			Total	**1**	
70	a		steam **AND** Acid/H^+ (catalyst) ✓	1	**Examiner's Comments** Many candidates knew the answer to this question but forgot that water must be in the gaseous state. There were numerous responses stating nickel as the catalyst, but most knew that an acid catalyst was required.
	b	i	1,2-dibromo-1,1-dichloroethane✓	1	**Examiner's Comments** This question was generally well answered, although some candidates made careless mistakes such as not writing -di or writing 1,2-dibromo-1-dichloroethane
		ii	 **1st curly arrow (from ANY alkene)** Curly arrow from double bond to Br of Br–Br ✓ **DO NOT ALLOW** partial charge on C=C **2nd curly arrow** Correct dipole on Br Br **AND** curly arrow for breaking of Br–Br bond ✓ **3rd curly arrow** **Correct carbocation** with + charge on C with 3 bonds **AND** curly arrow from Br^- to C^+ of carbocation ✓ **DO NOT ALLOW** δ+ on C of carbocation	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** **1st curly arrow** must • go to a Br atom of Br–Br • **AND** • start from, **OR** be traced back to **any point across width** of C=C  **2nd curly arrow** must • start from, **OR** be traced back to, **any part of** $^{\delta+}$Br–$^{\delta-}$ bond • **AND** go to $^{\delta-}$  **3rd curly arrow** must

			 *i.e. ALLOW carbonium + on either C atom* **DO NOT ALLOW** half headed or double headed arrows but allow **ECF** if seen more than once		• go to the C^+ of carbocation • **AND** • start from, **OR** be traced back to **any point across width** of lone pair on :Br^- • **OR** start from – charge on Br– ion  *(Lone pair **NOT** needed if curly arrow shown from – charge on Br^-)* **<u>Examiner's Comments</u>** Many candidates gained all three marks on this question and the diagrams were clear and easy to read. Lower ability candidates had incorrect dipoles or curly arrows that could not be traced back to the correct origin. Candidates should be encouraged to consider what the arrows mean rather than memorising mechanisms with no understanding.
	c	i	 Correct polymer with side links and brackets ✓ Equation balanced with *n* ✓ **TAKE CARE** of '*n*' position on both sides of equation.	2	**For repeat unit,** • displayed formula required • 'side bonds' required on either side of repeat unit from C atoms • **ALLOW** section containing more than one repeat unit **DO NOT ALLOW ECF** from incorrect repeat unit *n* on LHS at any height to the left of the formula *n* on RHS must be subscript **<u>Examiner's Comments</u>** Most candidates correctly drew the repeat unit and were credited with one mark, but many placed the *n* position in the wrong place on the left-hand side of the equation or forgot to write it in at all.
		ii	**Advantage (1 mark)** Energy production / (energy) used to produce electricity ✓ **Disadvantage (1 mark)** Formation of HCl/products of combustion cause acid rain **OR**	2	**ALLOW** reduced use of fossil fuels **ALLOW** less landfill / less harm to wildlife **ALLOW** chlorine/Cl **OR** Cl_2

<table>
<tr><td></td><td></td><td></td><td>Formation of CO_2/gases that cause global warming / greenhouse gases
OR
Formation of CO✓</td><td></td><td>**ALLOW** toxic/poisonous waste products

<u>Examiner's Comments</u>

With all the media interest in plastic pollution this question was answered well, although many gave the answer 'quick and efficient' as an advantage which was not credited. Candidates should beware of vague statements such as these. Many wrote 'harmful' instead of toxic, or 'bad for the environment' instead of being specific about the environmental issue.</td></tr>
<tr><td></td><td></td><td></td><td>**Total**</td><td>**9**</td><td></td></tr>
<tr><td>71</td><td></td><td></td><td>*Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.*

Level 3 (5-6 marks)
A comprehensive description including most of the evidence to justify the correct structure of **F** (accept *cis* or *trans*).
There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)
The candidate attempts all three scientific points, but explanations are incomplete.
OR
Explains two scientific points thoroughly with few omissions.
AND
an attempt at a feasible structure based on deduction from correct molecular formula
There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)
The correct empirical formula
AND a simple description based on at least one of the main scientific points.
OR
The candidate explains one scientific point thoroughly with few omissions.
There is an attempt at a logical structure</td><td>6</td><td>**LOOK AT THE SPECTRA** for labelled peaks
Indicative scientific points may include:

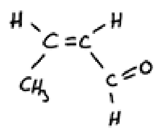
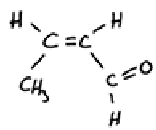
<u>Empirical formula</u>

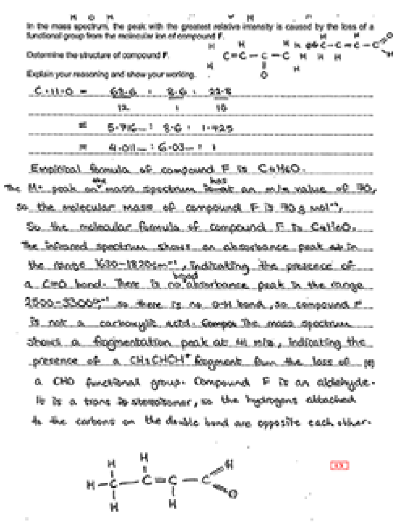
• empirical formula = C_4H_6O
<table><tr><th>element</th><th>% mass</th><th>Ar</th><th>moles</th><th>ratio</th></tr><tr><td>C</td><td>68.6</td><td>12</td><td>5.72</td><td>4</td></tr><tr><td>H</td><td>8.6</td><td>1</td><td>8.60</td><td>6</td></tr><tr><td>O</td><td>22.8</td><td>16</td><td>1.43</td><td>1</td></tr></table>
<u>IR and spectra and molecular formula</u>

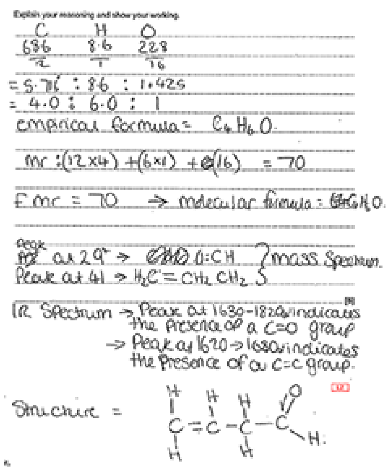
• infrared absorption; 1630–1820 cm^{-1}, due to C=O (aldehyde/ketone/carbonyl group)
• molar mass = 70 g mol^{-1} (mass spectrum molecular ion peak *m/z* = 70)
• molecular formula = C_4H_6O

<u>Functional groups, structure and stereochemistry</u>

• alkene / C=C
• aldehyde / −CHO ($C_3H_5^+$ fragment)
• mass spectrum; peak at 41 due to $C_3H_5^+$ (loss of CHO)
• *E/Z or cis-trans* isomer: *E/Z or cis-trans* isomer:

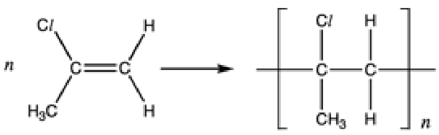

cis

trans (correct structure)</td></tr>
</table>

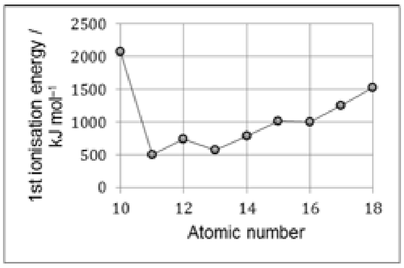
			with a line of reasoning. The information is in the most part relevant. **0 marks** No response or no response worthy of credit.		**Examiner's Comments** This question was a good discriminator. Most candidates were able to deduce the empirical formula and the C=O peak on the IR spectrum. However, many mistook the C-H peaks around 3000 cm^{-1} for an alcohol O-H peak or assumed from the empirical formula that it was an alcohol so made the spectra 'fit' their hypothesis. At AS, the exposure of candidates to IR and MS spectra is not as comprehensive as in the second year of A Level and this was evident. There was very little annotation of the spectra and candidates should be encouraged to do this as it is helpful to them in their deductions (and to the examiners for crediting marks). Analysis of the IR spectrum was much more detailed than the mass spectrum. Most candidates just referred to the molecular ion peak and made no attempt, or an incorrect attempt, at discerning the peak at 41. Those that did quickly realised what the structure was and gained 5 or 6 marks. Some candidates, despite ascertaining that a *trans* stereoisomer should be drawn, drew the *cis* version instead. **Exemplar 5**  In the mass spectrum, the peak with the greatest relative intensity is caused by the loss of a functional group from the molecular ion of compound F. Determine the structure of compound F. Explain your reasoning and show your working. C : H : O = 69.6/12 : 8.6/1 : 22.8/16 = 5.716... : 8.6 : 1.425 = 4.011... : 6.03... : 1 Empirical formula of compound F is C4H6O. The M+ peak on the mass spectrum has an m/z value of 70, so the molecular mass of compound F is 70 g mol-1, So the molecular formula of compound F is C4H6O. The infrared spectrum shows an absorbance peak in the range 1630-1820cm-1, indicating the presence of a C=O bond. There is no broad absorbance peak in the range 2500-3300cm-1 so there is no O-H bond, so compound F is not a carboxylic acid. The mass spectrum shows a fragmentation peak at 41 m/z, indicating the presence of a CH3CHCH+ fragment from the loss of a CHO functional group. Compound F is an aldehyde. It is a trans stereoisomer, so the hydrogens attached to the carbons on the double bond are opposite each other. This candidate has very logically worked through all the information provided and has come up with the correct structure from the deductions.

					Exemplar 6  Like most candidates, the crucial information about F being a *trans* isomer was not picked up so they drew the double bond in the wrong place.
			Total	**6**	
72		i	$Br_2(l) \rightarrow Br_2(g)$ ✓	1	**Examiner's Comments** A good attempt by many candidates but some lost marks by having the wrong state of bromine, even though the question stated it was a liquid changing to a gas. Many added water or oxygen, some confused the equation with bond enthalpy and answers such as $Br_{2\,(l)} \rightarrow 2Br_{(g)}$ were commonly seen.
		ii	Endothermic **AND** Energy required to overcome induced dipole–dipole forces/London forces ✓	1	**Mark independently of 3 (d) (i)** **ALLOW** endo to break **intermolecular** forces/bonds **ALLOW** bonds between molecules **DO NOT ALLOW** van der Waals' forces **Examiner's Comments** The majority of candidates answered this question incorrectly. Only 10% of candidates mentioned intermolecular/London forces. Most stated 'exothermic' or described breaking covalent bonds.
			Total	**2**	
73		i	$(1s^2)\ 2s^22p^63s^23p^63d^{10}4s^24p^4$ ✓	1	**ALLOW** subscripts **ALLOW** in any order i.e. $3d^{10}$ after $4s^2$ or

		i	Look carefully at $(1s^2)\ 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake		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_2Se / Hydrogen selenide / Selenium hydride ✓ **Equation** $Na_2Se + 2HCl \rightarrow 2NaCl + H_2Se$ All formulae and balancing ✓	2	**ALLOW** SeH_2 **ALLOW** correct multiples **IGNORE STATE SYMBOLS** **DO NOT ALLOW** H_2S for gas B **BUT ALLOW ECF** from H_2S for equation: $Na_2S + 2HCl \rightarrow 2NaCl + H_2S$ **<u>Examiner's Comments</u>** The majority of candidates obtained 1 or 2 marks on this question. The most common errors seen were identifying the gas as H_2S or incorrect balancing.
			Total	**3**	
74	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(HCl) = (0.100)(answer to **(c)(i)**/1000) = 0.00222 (mol) (1) $n(M_2CO_3)$ = 0.00222/2 = 0.00111 (mol) (1)	2	**allow ecf** from **(b)(i)**
		ii	$n(M_2CO_3)$ in total = 0.00111 x 10 = 0.0111 mol (1)	4	

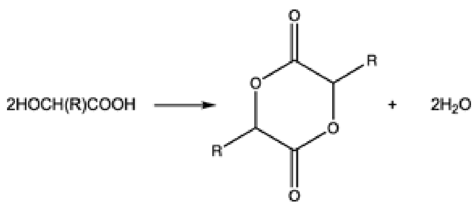
			Molar mass = 1.58/0.0111 = 142.3 g mol^{-1} (1) Mass of M = (142.3 − 60)/2 = 41.15 (= K) (1) K_2CO_3 (1)		**Note**: molar mass is between K_2CO_3 (138.2) and $SrCO_3$ (147.6); only possible match for a Group 1 carbonate is K_2CO_3.
			Total	**8**	
75		i	$P_4 + 6Br_2 \rightarrow 4PBr_3$	1	**ignore** state symbols
		ii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **If answer = 3.01 × 10^{21} award 3 marks** $M_r(PBr_3)$ = 270.7 (g mol^{-1}) (1) $n(PBr_3)$ = 1.3535 / 270.7 = 5.000 × 10^{-3} mol (1) number of molecules = 5.000 × 10^{-3} × 6.02 × 10^{23} = 3.01 × 10^{21} molecules (1)	3	If there is an alternative answer, check to see if there is any **ecf** credit possible using working below. **allow** in working shown as 28.1 + 35.5 × 4 **allow ecf** from incorrect molar mass of PBr_3 **allow** 0.005(00) (mol) for two marks **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 **do not allow** any marks for: 1.3535 × 6.02 × 10^{23} = 8.15 × 10^{23}
		iii	Pyramidal (1) (because there are) 3 bonded pairs and 1 lone pair (around the central phosphorus atom) (1) and electron pairs repel each other as far apart as possible so will take on a tetrahedral arrangement (giving a pyramidal shape overall) (1)	3	
			Total	**7**	
76		i	**2** Al(s) + **6** $CH_3COOHCaq) \rightarrow$ **2** $(CH_3COO_3Al(aq)$ + **3** $H_2(g)$ ✓	**1**	**ALLOW** multiples, e.g. Al(s) + **3**$CH_3COOH(aq) \rightarrow (CH_3COO)_3A1(aq)$ + **1**½$H_2(g)$ **Examiner's Comments** The majority of candidates were able to balance this equation using whole numbers or half multiples. Where there was an error, it was invariably for the balancing number of H_2.

		ii	Element oxidised: aluminium/Al 0 to +3 ✓ Element reduced: hydrogen/H +1 to 0 ✓	**2**	**ALLOW** 3+ for +3 and 1+ for +1 **ALLOW** H_2 for hydrogen **ALLOW** 1 mark for elements **AND** all oxidation numbers correct, but H in oxidised line and Al in reduced line '+' is required in +3 and +1 oxidation numbers **IGNORE** numbers around equation *(treat as rough working)* **Examiner's Comments** This question was not answered as well as expected. It was pleasing to see that almost all candidates recognised the importance of writing oxidation numbers correctly including a '+' or '−' sign where needed. Common mistakes included giving the total contribution from an element as opposed to the oxidation state of each atom of the element.
			Total	**3**	
77		i	 Correct repeat unit (*n* and brackets not required) ✓ Equation balanced with *n* ✓ **TAKE CARE** of '*n*' position on both sides of equation.	**2**	**For monomer,** **ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **For repeat unit,** **DO NOT ALLOW** molecular formula **NOTE**: 'side bonds' **ARE** required on either side of repeat unit from C atoms **ALLOW** section of polymer containing more than one repeat unit **NO ECF** from incorrect repeat unit **Examiner's Comments** The majority of candidates correctly drew the repeat unit but only afew wrote a full equation, balanced with *n*. The most common error was omission of the '*n*' before the monomer. Candidates are reminded of the importance of balancing equations.
		ii	Formation of HCl/hydrochloric acid/ **OR** chlorine ✓	**1**	**ALLOW** Cl or Cl_2 for chlorine **IGNORE** toxic waste products *Response must reflect chlorine in some way*

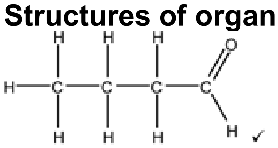
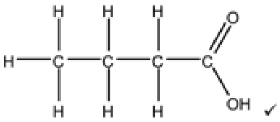
					Examiner's Comments Most candidates realised that the combustion would produce toxic/harmful gases, but the majority either incorrectly identified the problem gas as CO_2/CO or did not identify the gas at all. Others referred to ozone damage and global warming. Good responses referred to the formation of chlorine compounds such as hydrogen chloride.
			Total	**3**	
78		i	 Ne (Z = 10) shown **higher** than 1500 (i.e. > Ar) ✓	**1**	**Look carefully for small dots on the y axis** **IGNORE** no straight line from Ne (10) to Na (11) **Examiner's Comments** This part was poorly attempted with only the most able candidates adding a point on the graph above 1500.
		ii	$\frac{500}{6.02 \times 10^{23}} = 8.3 \times 10^{-22}$ (kJ) ✓ Answer **MUST** be to 2 SF **AND** in standard form.	**1**	**ALLOW** use of IEs close to 500 giving a range: $8.0 \times 10^{-22} - 8.6 \times 10^{-22}$ i.e. $8.3 \pm 0.3 \times 10^{-22}$ **Examiner's Comments** Very few candidates realised the need to use the Avogadro constant, with most candidates responded with 500, or 5.00 $\times 10^{-2}$ in standard form, the energy for one mole. Many candidates did not seem to know the meaning of standard form and there was some confusion between significant figures and decimal places, all basic mathematical concepts and requirements for Chemistry AS. Answer: = 8.3×10^{-22} kJ
		iii	*Nuclear charge*	**3**	**FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED** Comparison should be used for each mark **IGNORE** atomic number increases

			number of protons/proton number increases **OR** greater **nuclear** charge ✓ *Distance/shielding* (Outer) electrons are in the same shell **OR** (Outer) electrons experience the same/similar shielding **OR** Atomic radius decreases ✓ *Attraction* **Greater** nuclear attraction (on outer electrons) **OR** (outer) electrons are attracted more strongly (to the nucleus) ✓		**IGNORE** nucleus gets bigger **IGNORE** 'effective nuclear charge increases' **IGNORE** same sub-shell **OR** same orbital **IGNORE** 'there is shielding' **ALLOW** 'greater repulsion from inner shells' **ALLOW** 'pull' for 'attraction' **IGNORE** just 'greater attraction' **OR** greater force **IGNORE** 'held' for attracted, *e.g. IGNORE 'held' more strongly* **Examiner's Comments** This part was answered well, with many stock answers seen in terms of atomic size, nuclear charge and attraction. Weaker candidates often produced long responses that lacked focus, which often obtained fewer marks than short concise answers.
		iv	***Sub-shells*** Mg electron is removed from (3)s **AND** Al electron is removed from (3)p ✓ ***Energy levels*** Al electron has a higher **energy** **OR** (3)p has higher energy than (3)s ✓	**2**	**IGNORE** number before s and p *e.g. ALLOW (2)s and (2)p* **ALLOW** response implying that orbitals/sub-shell changes from s to p **IGNORE** comments about distance from nucleus **IGNORE** 'less energy to remove' **DO NOT ALLOW** unpaired electron removed more easily (**ORA**) **Examiner's Comments** Few candidates answered this part well. Candidates were expected to realise that Mg loses an electron from an s orbital, whereas Al loses an electron from a higher energy p orbital. There were few clear answers and many candidates were distracted by paired and unpaired electrons or distance from the nucleus.

					Few candidates responded in terms of the difference in energy between the s and p orbitals.
			Total	**7**	
79		i	$(1s^2)\ 2s^2\ 2p^6$ ✓	**1**	**IGNORE** $1s^2$ seen twice **ALLOW** upper case letters **AND** subscripts **Examiner's Comments** Many incorrect answers but I am happy to report that the use of incorrect notation, mentioned in last year's report, was not an issue in the 2017 paper.
		ii	*Products of reaction* **A** = Barium hydroxide / $Ba(OH)_2$ ✓ **B** = Ammonia / NH_3 ✓ *Formula for barium nitride* Ba_3N_2 ✓ *Balanced equation **AND** state symbols* $Ba_3N_2(s) + 6H_2O(l) \rightarrow 3Ba(OH)_2(aq) + 2NH_3(g)$ ✓ State symbols **are** required	**4**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** one mark for correct products incorrectly labelled Formulae must be correct No **ECF from any incorrect formula** **ALLOW** multiples Correct equation with state symbols scores 4 marks **Examiner's Comment:** This question discriminated well and only the most able candidates were able to score full marks with a correctly balanced equation including state symbols. Weaker candidates were able to pick up some marks for identifying barium hydroxide or ammonia, although barium oxide and nitrogen were not uncommon. Some failed to score the more accessible marks because they used an incorrect formula instead of writing the name of the product.
			Total	**5**	
80		i	***Equation*** $2HOCH(R)COOH + Mg \rightarrow (HOCH(R)COO)_2Mg + H_2$ Organic product ✓	**3**	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non- ambiguous **ALLOW** $2HOCH(R)COOH + Mg$ $\rightarrow 2HOCH(R)COO^- + Mg^{2+} + H_2$ **ALLOW** multiples **IGNORE** poor connectivity to OH groups *Given in question*

			Balance ✓ ***Type of reaction*** Redox ✓		**Examiner's Comment:** Candidates found this part difficult and the problem presented many opportunities for errors. Many candidates tried to show charges for the salt formed but often the 2+ charge was missing on Mg^{2+} or Mg^{+} was shown. The balanced equation required a balancing 2 before compound A but this was often omitted. Candidates using skeletal formulae fared better than attempts to show structural formulae such as HOCHRCOOH, with many omitting the H atom from CHR. Few candidates identified the reaction as redox, with many giving neutralisation instead.
		ii	***Equation***  Organic product ✓ Balance ✓ ***Type of reaction*** Condensation **OR** esterification ✓	**3**	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non- ambiguous **ALLOW** 1 mark of the 2 equation marks for formation of '3 ring' with balanced equation:  **ALLOW** condensation polymerisation **ALLOW** addition–elimination **IGNORE** elimination **IGNORE** dehydration **Examiner's Comment:** As with 4(b)(ii), candidates found this question difficult. It was not often that the dimer was seen but, when it was, the structure was usually correct. Balancing required $2H_2O$ and the balancing 2 was often omitted. In contrast with 4(b)(i), many more candidates identified the type of reaction, here condensation or esterification.
			Total	**6**	
81			**ALLOW** equilibrium sign in equations provided reactants on left	**4**	**ALLOW** correct multiples **IGNORE** state symbols ……………………………………………… **ALLOW** uncancelled H_2O and H^+ $H_2O_2 + MnO_2 + \mathbf{4}H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$

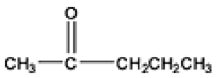
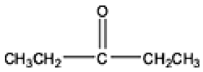
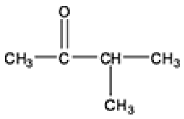
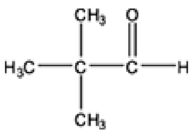
			Reaction of H_2O_2 with MnO_2: $H_2O_2 + MnO_2 + 2H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$ ✓ **Reaction of H_2O_2 with Mn^{2+}:** $H_2O_2 + Mn^{2+} \rightarrow MnO_2 + 2H^+$ ✓ **Use of *E* data** Use of *E* data to support equation(s) above or half direction of provided half equations (one including MnO_2) ✓ *Also look for evidence around half equations* MnO_2 regenerated / reformed ✓ *Must be linked to an equation showing MnO_2 as reactant and an equation showing MnO_2 as product*		**+ $2H^+$** $H_2O_2 + Mn^{2+}$ **$+ 2H_2O + 2H^+$** $\rightarrow MnO_2 +$ **4**H^+ **$+ 2H_2O$** ***Examples*** • More negative *E* moves to left **ORA** • Reduction half equation to the right **ORA** • Most positive *E* is reduced **ORA** • Calculated *E* cell = +0.81 V (*from top* 2) **OR** +*0.27 V (from bottom 2)* **ALLOW** combining of equations above to show that MnO_2 is used and reformed **Examiner's Comment:** Many candidates found this part challenging and there was a wide variety of answers and marks awarded. There were two equations to construct showing how MnO_2, and Mn^{2+} react with H_2O_2. Many combined the two equations involving H_2O_2 to obtain the overall equation for the decomposition of H_2O_2 which was given at the top of the paper. Of the equations seen, many had species uncancelled. Many candidates only tackled one of the equations. Candidates were expected to provide evidence for their equations based on the electrode potentials provided. Use of this data was patchy and only the best candidates linked the relative *E* values to the direction of movement or redox details. A significant number gave cell potentials. Regeneration of MnO_2 was well understood but often just stated with no reference to the equations. This part discriminated very well.
			Total	**4**	

82	a		$C_5H_{10}O + 7O_2 \longrightarrow 5CO_2 + 5H_2O$ ✓	**1**	**ALLOW** multiples e.g. $2C_5H_{10}O + 14O_2 \longrightarrow 10CO_2 + 10H_2O$ **ALLOW** any equation involving an unsaturated alcohol with correct balancing **e.g.** $C_5H_8O + 6.5O_2 \longrightarrow 5CO_2 + 4H_2O$ $C_5H_6O + 6O_2 \longrightarrow 5CO_2 + 3H_2O$ $C_5H_4O + 5.5O_2 \longrightarrow 5CO_2 + 2H_2O$ $C_5H_2O + 5O_2 \longrightarrow 5CO_2 + H_2O$ **IGNORE** state symbols **Examiner Comments** The more able candidates were able to balance this combustion equation. Those who failed to be awarded the mark either used the molecular formula of a saturated alcohol or did not consider the presence of the oxygen atom in the alcohol when balancing the equation.
	b		**Structures of organic products**   **Equations** $CH_3CH_2CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CH_2CHO + H_2O$ ✓ $CH_3CH_2CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2CH_2COOH + H_2O$ ✓ **Reaction conditions** Distillation to produce aldehyde/$CH_3CH_2CH_2CHO$ **AND** Reflux to produce carboxylic acid/$CH_3CH_2CH_2COOH$ ✓	**5**	**ANNOTATE WITH TICKS AND CROSSES** Use of any primary alcohol containing 3, 5 or more carbons can be awarded up to 4 marks. **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names **DO NOT ALLOW** $CH_3CH_2CH_2COH$ for the structure of the aldehyde. **ALLOW** $CH_3CH_2CH_2CO_2H$ for the structure of the carboxylic acid. **ALLOW** marks for structures from equations as long as unambiguous. **ALLOW** molecular formulae in equations e.g. $C_4H_{10}O + [O] \longrightarrow C_4H_8O + H_2O$ $C_4H_{10}O + 2[O] \longrightarrow C_4H_8O_2 + H_2O$ $C_4H_9OH + [O] \longrightarrow C_3H_7CHO + H_2O$ $C_4H_9OH + 2[O] \longrightarrow C_3H_7CO_2H + H_2O$ **IGNORE** incorrect structures in equations i.e. $C_4H_{10}O + [O] \longrightarrow C_3H_7COH + H_2O$ scores equation mark Conditions **must** be linked to aldehyde/carboxylic acid or correct products. Conditions may be written above arrow of equation. **Examiner Comments**

					A very well answered question. Candidates had obviously been well prepared as even the weakest candidates gained a number of marks here. The most common mark lost was a failure to include H_2O in the balanced equations. In the preparation of the carboxylic acid, a number of Candidates balanced the equation with $2H_2O$.
			Total	**6**	
83		i	$n(\text{myrcene}) = \frac{204 \times 10^{-3}}{136.0} = 1.5(0) \times 10^{-3}$ (mol) ✓ Volume of H_2 $= 3 \times 1.5(0) \times 10^{-3} \times 24000$ $= 108$ (cm^3) ✓	**2**	Correct working **required** for the first marking point. **ALLOW ECF** from incorrect moles of myrcene i.e. *n*(myrcene) × 3 × 24000 **Common incorrect answers** 108000 cm^3 = 1 mark (not converted to g) 12cm^3 = 1 mark (divided by 3) 36 cm^3 = 1 mark (not multiplied by 3) **IGNORE** Calculations based on $pV = nRT$ **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 cm^3 to provide an answer in cm^3. Candidates who worked in mg could not access the first mark however the subsequent mark was awarded as error carried forward. Answer = 108 cm^3
		ii	**Amount of hydrogen** $n(H_2) = \frac{5.28}{24.0} = 0.22(0)$ (mol) ✓ **Number of double bonds** $= \frac{0.220}{0.0200} = 11$ ✓ **Formula of saturated product** $C_{40}h_{78}$ **Equation** $C_{40}H_{56} + 11H_2 \longrightarrow C_{40}H_{78}$ ✓	**4**	**ALLOW** Evidence of $n(H_2) = \frac{5.28}{24.0}$ if 0.22 is not seen Evidence for 11 double bonds could come from $11H_2$ in equation Formula could be shown as the product of an equation **ALLOW ECF** from $C_{40}H_{82}$ and $C_{40}H_{80}$ **only** i.e. $C_{40}H_{60} + 11H_2 \longrightarrow C_{40}H_{82}$ $C_{40}H_{58} + 11H_2 \longrightarrow C_{40}H_{80}$

					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
			Total	**6**	
84			**C**	1	
			Total	**1**	
85	a	i	**Reagent and observation** sodium carbonate **AND** Fizzing/effervescence/bubbling ✓ **Equation** Correctly balanced equation ✓ e.g. $2RCOOH + Na_2CO_3 \rightarrow 2RCOONa + CO_2 + H_2O$	2	**Note:** both reagent and observation are required for first mark **ALLOW** name or formula for any suitable carbonate e.g $NaHCO_3$, potassium carbonate etc. **ALLOW** reagent from equation if not stated elsewhere
		ii	**Reagent and observation** Tollens' (reagent) **AND** Silver (mirror) ✓ **Equation** $RCHO + [O] \rightarrow RCOOH$ ✓	2	**Note:** both reagent and observation are required for first mark **ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** $H^+/Cr_2O_7^{2-}$ **OR** acidified (potassium/sodium) dichromate **AND** Orange to green *(this would identify the aldehyde from the carboxylic acid, ketone and esters)*
	b		2,4−dinitrophenylhydrazine **AND** Orange/yellow/red precipitate ✓	1	**ALLOW** errors in spelling **ALLOW** 2,4(−)DNP **OR** 2,4(−)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate
	c	i	$CH_3COOC(CH_3)_3 + NaOH \rightarrow CH_3COONa + (CH_3)_3COH$	2	**Note:** the hydrolysis of either ester may be given

			CH_3COONa ✓ Rest of equation correct ✓ **OR** $(CH_3)_3CCOOCH_3 + NaOH \rightarrow (CH_3)_3CCOONa + CH_3OH$ $(CH_3)_3CCOONa$ ✓ Rest of equation correct ✓		**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** molecular formulae of products *(question requires structures of products to be shown)*
		ii	**Reagent and observation** $H^+/Cr_2O_7^{2-}$ **OR** acidified (potassium/sodium) dichromate **AND** Orange to green (with CH_3OH) ✓ **Equation** $CH_3OH + [O] \rightarrow HCHO + H_2O$ **OR** $CH_3OH + 2[O] \rightarrow HCOOH + H_2O$ ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** molecular formulae *(question requires structures of organic compounds to be shown)*
		iii	**^{13}C NMR (1 mark)** (It is) not possible to identify (the esters) with ^{13}C NMR **AND** (both) spectra would contain four peaks (with similar chemical shifts) ✓ **^{1}H NMR (2 marks)** (It is) possible to identify (the esters) with ^{1}H NMR (^{1}H NMR spectrum of) $CH_3COOC(CH_3)_3$ has a singlet/peak between 2.0−3.0 (ppm) (^{1}H NMR spectrum of) $(CH_3)_3CCOOCH_3$ has a singlet/peak between 3.0−4.3 (ppm) All **three** correct statements✓✓ Any **two** correct statements ✓	3	**ALLOW** 'same number of peaks' in place of 'four peaks' **ALLOW** any value or range of values within 2.0−3.0 **ALLOW** any value or range of values within 3.0−4.3

			Answer	Marks	Guidance
	d		**Possible structures for ketone (2 marks)**    All **three** correct ✓✓ Any **two** correct ✓ **Aldehyde (3 marks)** Peak at (δ) 1.2 shows HC–R **AND** No H on adjacent C atom as peak is singlet ✓ Peak at (δ) 9.6 shows H–C=O **AND** No H on adjacent C atom as peak is singlet ✓  **OR** (2,2−)dimethylpropanal ✓	5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** names of ketones
			Total	**17**	
86		i	$CF_3Cl \rightarrow CF_3\bullet + Cl\bullet$ ✓	1	**Note:** dots are **required**
		ii	Step 1: $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ ✓ Step 2: $ClO\bullet + O \rightarrow Cl\bullet + O_2$ ✓ Overall equation: $O_3 + O \rightarrow 2O_2$ ✓	3	**ALLOW** one mark for both correct symbol equations in propagation steps with (any or all) dots missing or extra dots. e.g. $Cl\bullet + O_3\bullet \rightarrow ClO + O_2$ $ClO\bullet + O\bullet \rightarrow Cl + O_2\bullet$
		iii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 9.98×10^4 award 3 marks $n(Cl\bullet) = \frac{1}{35.5} = 0.02817$ (mol) ✓ $n(O_3) = \frac{135000}{48} = 2812.5$ (mol) ✓	3	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW** 0.0282 up to calculator value of 0.02816901408 correctly rounded to 3 or more sig. fig. **ALLOW 3SF**: 2810 up to calculator value

			$n(\text{C}l\bullet) : n(\text{O}_3) = \frac{2812.5}{0.02817} = 9.98 \times 10^4$ ✓ *Must be in standard form* ***AND*** *to 3SF*		of 2812.5 correctly rounded **Note**: use of 0.0282 mol C*l*• gives 9.97×10^4
			Total	**7**	
87	a	i	(enthalpy change for) the formation of **1 mole H_2O** from reaction of an acid/H^+ with an alkali/base/OH^- ✓ $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ ✓	2	**ALLOW** (enthalpy change for) the reaction of 1 mol H^+ with 1 mol of OH^- **ALLOW** formation of 1 mol of water from neutralisation If no definition in words, award 1st mark if 1 mol is written under species in the equation, in line with marking criteria **DO NOT ALLOW** formation of 1 mol H_2O from 1 mole of acid and/or 1 mol of alkali **DO NOT ALLOW** formation of 1 mol H_2O from an acid and its conjugate base
		ii	$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ ✓	1	**IGNORE** state symbols (even if wrong) *not required*
		iii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer =** −56.43 **OR** −56.4 (kJ mol^{-1}) award 3 marks .... ***Energy change*** energy change = 75.0 × 4.18 × 13.5 = 4232.25 (J) **OR** 4.23225 (kJ) ✓ ***Moles*** $n(\text{NaOH}) = 1.5(0) \times \frac{50.0}{1000} = 0.075(0)$(mol) **OR** $n(H_2SO_4) = 1.5(0) \times \frac{25.0}{1000} = 0.0375(0)$ (mol) **OR** $n(H_2O)$ formed =0.075(0) (mol) ✓ $\Delta_{neut}H = -\frac{4.23225}{0.075} = -56.43$ **OR** −56.4 (kJ mol^{-1}) ✓ − sign **required**	3	**FULL ANNOTATIONS MUST BE USED** .... **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below .... **IGNORE** any sign shown **ALLOW** 4230 (J) **AND** 4.23 (kJ) up to calculator value correctly rounded **ALLOW ECF** from $\frac{\text{calculated energy change}}{\text{calculated moles } H_2O}$ **ALLOW** 3 significant figures up to calculator value correctly rounded

	b	i	$2H_2S(g) + O_2(g) \longrightarrow 2S(s) + 2H_2O(g)$ ✓	1	**ALLOW** multiples, e.g. $6H_2S(g) + 3O_2(g) \longrightarrow 6S(s) + 6H_2O(g)$
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer =** 3.05×10^7 (g) award 3 marks .... volume of H_2S $= 1.50 \times 10^8 \times 16(0)/100 = 2.4(0) \times 10^7$ dm^3 of H_2S ✓ n (H_2S) (= n(S)) $2.4(0) \times 10^7/24.0$ mol = $1(.00) \times 10^6$ mol ✓ Mass S = $1(.00) \times 10^6 \times 95(.0)/100 \times 32.1$ $= 3.05 \times 10^7$ (g) ✓	3	**ALLOW ECF** from incorrect volume of H_2S **3 SF AND standard form** required
	c	i	**FIRST, CHECK FOR A VALUE OF Δ*G*.** **IF** answer = − 89.96(34) (kJ mol^{-1}) award **3 marks** .... **Δ*S* calculation (2 marks)** Δ*S* = (3 × 31.8) + (2 × 188.7) − [(2 × 205.7) + (248.1)] **OR** Δ*S* = 472.8 − 659.5 ✓ Δ*S* = −186.7 J mol^{-1} K^{-1} **OR** −0.1867 kJ mol^{-1} K^{-1} ✓ **Δ*G* calculation (1 mark)** Δ*G* = Δ*H* − *T* Δ*S* = −145.6 − (298 × −0.1867) = − 89.96(34) (kJ mol^{-1}) ✓ **Comment (1 mark)**− sign shows the (forward) reaction is feasible ✓ **Temperature at which feasibility changes (1 mark)** $T = \frac{\Delta H}{\Delta S} = \frac{-145.6}{-0.1867}$ = 780 k **AND** comment that Δ*G* **OR** Δ*H* − *T*Δ*S* = 0 ✓	5	**ALLOW** (−) 187 OR 0.187 **ALLOW ECF** from incorrect Δ*H* **ALLOW** −90 up to calculator value of −89.9634 correctly rounded **ORA** for comment about − sign required for feasibility
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer** = −296.8 (kJ mol^{-1}) award 2	2	

			marks .... **Correct expression**−145.6 = (2 × −241.8) − (2 × −20.6 + Δ_fH(SO2)) ✓ **Calculation of $\Delta_f H(SO_2)$ formation** $\Delta_f H(SO_2)$ = (2 × −241.8) − (2 × −20.6) + 145.6 = −**296.8** (kJ mol^{-1}) ✓		**ALLOW ECF** **ALLOW** 1 mark for (+)296.8 *Subtraction the wrong way around*
			Total	**17**	
88	a		Cu^{2+}: ($1s^2$) $2s^22p^63s^23p^63d^9$ ✓ Cu^+: ($1s^2$) $2s^22p^63s^23p^63d^{10}$ ✓	2	**IGNORE** repeated $1s^2$ after $1s^2$ prompt on answer line **ALLOW** $4s^0$, either before or after 3d **ALLOW** upper case D, etc and subscripts, e.g.......$3S_23P^6$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ **Examiner's Comments** The responses seen were very mixed. Able candidates scored the two marks easily but many errors were seen, particularly by removal of 3d electrons rather than 4s electrons from copper atoms to give the electron configurations of the ions (especially for Cu^+ in CuI).
	b		**IGNORE** any charges shown within formulae (treat as rough working) $CuCO_3$ + 2HCOOH → $Cu(HCOO)_2$ + H_2O + CO_2 **OR** CuO + 2HCOOH → $Cu(HCOO)_2$ + H_2O **OR** $Cu(OH)_2$ + 2HCOOH → $Cu(HCOO)_2$ + **2**H_2O ✓	1	**IGNORE** state symbols In formula of HCOOH / HCOO, **ALLOW** H, C and O in **ANY** order **ALLOW** H_2CO_3 for H_2O and CO_2 in carbonate equation **ALLOW** $(HCOO)_2Cu$ for $Cu(HCOO)_2$ **DO NOT ALLOW** equation with $CuSO_4$ **Examiner's Comments** Most candidates attempted an equation using CuO, $Cu(OH)_2$ or $CuCO_3$. Marks were then sometimes lost by not balancing the equation. It was not uncommon to see equations using $CuSO_4$ or $CuCl_2$ as reactant and consequently this mark was often not awarded.
	c		$2Cu^{2+}$ + $4I^-$ → 2CuI**(s)** + I_2 ✓ State symbol for CuI(s) **ONLY** required	1	**ALLOW** multiples, e.g. Cu^{2+} + $2I^-$ → CuI**(s)** + ½I_2

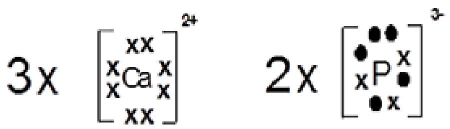
					IGNORE other state symbols, even if incorrect **Examiner's Comments** This equation proved to be much more difficult than in **8(b)**, with only the best candidates producing a correctly balanced equation. As with **4(c)** and **7(b)(iii)**, equations were often unbalanced in terms of charge and oxidation number.
	d		Starch ✓ Blue / black to colourless / white ✓ **MARK INDEPENDENTLY**	2	**IGNORE** 'brown' in composite colour with blue or black, i.e. **ALLOW** blue / brown to colourless **ALLOW** black / brown to colourless **DO NOT ALLOW** just 'it turns colourless / is decoloured' *Initial colour required* **IGNORE** clear for colourless **Examiner's Comments** Most candidates seemed unaware that starch is used to identify the end point in iodine–thiosulfate titrations. Even when starch was given, the colour change was often incorrect. Random responses were seen to this part, e.g. methyl orange, phenolphthalein, potassium manganate and sodium thiosulfate.
	e		**WORKING REQUIRED** Correct answer: x = 4 required evidence of working .... $n(S_2O_3^{2-})$ **OR** $n(Cu^{2+}) = \frac{0.0420 \times 23.5}{1000} = 9.87 \times 10^{-4}$ (mol) ✓ In 250.0 cm^3 solution, $n(Cu^{2+}) = 9.87 \times 10^{-3}$ (mol) ✓ $M(Cu(HCOO)_2{\bullet}4H_2O) = \frac{2.226}{9.87 \times 10^{-3}} = 225.5$ ($g\ mol^{-1}$) ✓ $\boldsymbol{x}(H_2O)$ has mass of 225.5 − $M(Cu(HCOO)_2)$ = 225.5 − 153.5 = 72(.0) ✓ $x = \frac{72(.0)}{18(.0)} = 4$ **WHOLE NUMBER** needed	5	***FULL ANNOTATIONS MUST BE USED*** .... At least **3 SF** required throughout *Alternative approach for final 3 marks based on mass:* mass $Cu(HCOO)_2 = 9.87 \times 10^{-3} \times 153.5 = 1.515$ g ✓ $n(H_2O) = \frac{2.226 - 1.515}{18(.0)} = \frac{0.711}{18(.0)} = 0.0395$ (mol) ✓ $x = \frac{0.0395}{9.87 \times 10^{-3}} = 4$ ✓ **ALLOW** $Cu(HCOO)_2{\bullet}4H_2O$ .... **COMMON ERRORS for 4 marks** $\boldsymbol{x}$ = 117 (calc 116.78)

			AND evidence of working ✓		*Use of 9.87 × 10^{-4} (no scaling × 10) → M* = 2255.319 ***x*** = 17 (calc 16.53) 4 marks *Use of 4.935 × 10^{-4} (Use of 0.5 × 9.87 × 10^{-3})* Check $n(Cu^{2+})$ for other **ECF**s Check for **ECF**s from incorrect *M*(anhydr salt) Actual = 153.5 **Examiner's Comments** Many candidates were on firm territory with a redox titration problem. The majority went through a well-rehearsed sequence of steps to obtain all five marks for showing that x was 4. Where '4' had not been obtained, marks could still be awarded for intermediate working if correct. Answer: x = 4
			Total	**11**	
89			$C_{17}H_{35}COOH + NaOH$ $\rightarrow C_{17}H_{35}COO^{-}Na^{+} + H_2O$ ✓	1	**ALLOW** $C_{17}H_{35}COONa$ **IGNORE** state symbols **Examiner's Comments** Very well answered. Most candidates could write the correct equation.
			Total	**1**	
90	a		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF $\Delta_r H$ = −58.5 (kJ mol^{-1}) award 4 marks** ***Energy released in J OR kJ*** = 100.0 × 4.18 × 10.5 = 4389 (J) **OR** 4.389 (kJ) ✓ ***Correctly calculates $n(Pb(NO_3)_2)$*** $= 1.50 \times \frac{50}{1000} = 0.075(0)$ (mol) ✓ **ΔH value in J OR kJ** *Answer **MUST** divide energy by $n(Pb(NO_3)_2)$* $(-)\frac{4389}{0.0750}$ **OR** (−)58520 (J) **OR**	4	***FULL ANNOTATIONS MUST BE USED*** **-----------------------------------** **ALLOW** 4390 J; 4.39 kJ **DO NOT ALLOW** less than 3 SF **IGNORE** units *i.e. **ALLOW** correctly calculated number in J **OR** kJ* **ALLOW ECF** from $n(Pb(NO_3)_2)$ **AND/OR** Energy **ALLOW** 58500 (from 4390) **IGNORE** absence of – sign and 3 SF

			(–) $\frac{4.389}{0.0750}$ **OR** (–)58.52 (kJ) ✓ *(Sign ignored and/or more than 3 SF)* Correct $\Delta_r H$ in kJ **AND** – sign AND 3 SF = –58.5 (kJ mol^{-1}) ✓		requirement Final mark requires – sign, kJ **AND** 3 SF **Note**: From 4390 J, $\Delta_r H$ = −58.5 (kJ mol^{-1}) (SAME) --- **Common error** −29.3 3 marks (50 g instead of 100 g in *mcΔT*) **Examiner's Comments** Although similar in style to unstructured direct enthalpy calculations on the legacy specification, this question was harder for two reasons. Firstly, two volumes of 50 cm^3 had to be added together to generate m as 100 g for *mc*Δ*T*. Secondly, candidates were asked to quote their final answer to an 'appropriate' number of significant figures. This will be the least accurate measurement (to 3 significant figures in this example). Many incorrect answers used *m* as 50 g or quoted a final numerical value to more than 3 significant figures. Even after obtaining a correct final value for Δ*H*, this was often not given a negative sign to indicate the exothermic change. It is important for candidates to show clear working so that markers can see what is intended and able to apply credit using error carried forward. Answer: Δ*H* = −58.5 kJ mol^{-1}
	b			$Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI^2(s)$ ✓ **State symbols required**	1	**ALLOW** $Pb^{+2}(aq)$ **IGNORE** spectator ions, $K^+(aq)$ and $2NO_3^-(aq)$ on both sides **Examiner's Comments** Only the best candidates were able to construct the required equation. Even when written correctly, state symbols (asked for in the question) were often omitted or shown incorrectly. Although very similar to the ionic equation for formation of silver halides, this equation

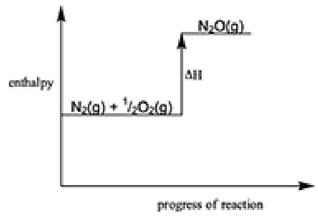
					was beyond most candidates at this stage of their chemistry studies.
	c		**FIRST, CHECK ANSWER ON ANSWER LINE** **IF [KI(aq)] rounds to 3.3 mol dm^{-3}** e.g. 3.30, 3.33, 3.3 recurring --- **Method 1** [KI(aq)] for complete reaction $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{50} = 3 \text{ (mol dm}^{-3}\text{)}$ ✓ 10% greater gives 3 × 1.1 = 3.3(0) ✓ **OR---** **Method 2** *n*(KI(aq)) required = 2.2 × 0.0750 = 0.165 mol ✓ $[\text{KI(aq)}] = 0.165 \times \frac{1000}{50} = 3.3(0) \text{ (mol dm}^{-3}\text{)}$ ✓	2	**ALLOW ECF** from incorrect *n*($Pb(NO_3)_2$) from **24(a)** **BUT** if **(a)** is incorrect but 0.0750 used here, treat as a fresh start and **IGNORE** response from **24(a)** **ALLOW** 2 marks for 3.3/3.3 recurring *Attempt at increasing concentration by 10%* $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{45} = 3.33 \text{ (mol dm}^{-3}\text{)}$ **ALLOW ECF** from incorrect *n*(KI) ______________________________ **Common errors** 3 — 1 mark (Correct for KI with no extra 10%) 1.65 — 1 mark (no factor of 2 used for KI) 2.7 — 1 mark (10% less rather than 10% more) 2.73/2.72 — 1 mark (10% increase in volume: 55 cm^3) **Examiner's Comments** This part was well attempted with many candidates able to score at least one of the two marks. Errors related to use of an incorrect mole ratio, applying 10% incorrectly, or ignoring 10% altogether. Answer: 3.30 mol dm^{-3}
			Total	**7**	
91			C	1	**Examiner's Comments** Distractor D was a common incorrect answer.
			Total	**1**	

92	a	i	Effervescence **OR** fizzing **OR** bubbling **OR** gas produced **AND** The solid **OR** zinc carbonate would dissolve **OR** disappear ✓	1	**ALLOW** 'carbon dioxide produced' **DO NOT ALLOW** incorrectly named gas eg H_2 **Examiner's Comments** Most candidates realised that effervescence and dissolving would be seen.
		ii	$ZnCO_3 + 2HCl$ ◊$ZnCl_2 + CO_2 + H_2O$ ✓	1	**ALLOW** multiples **IGNORE** state symbols **Examiner's Comments** Nearly all candidates were able to write the equation successfully – including those who had omitted effervescence in (i).
	b	i	Magnesium (atoms) has been oxidised **AND** Because it has lost **two** electrons ✓ Copper (ions) has been reduced **AND** Because it has gained **two** electrons ✓	2	**IGNORE** use of oxidation numbers if electron gain/loss is mentioned. Electrons gain/loss could be in half equations In the absence of text look for evidence on the equation **ALLOW** 'donated' for 'lost' Assume 'Cu' refers to copper in '$CuSO_4$' **ALLOW** one mark **two** electrons gained and lost for each species but oxidation/reduction is incorrect or is omitted **ALLOW** one mark for correct oxidation and reduction if electron transfer is **omitted** and correct changes of oxidation state are shown (ie Mg 0 --> (+)2 **AND** Cu (+)2 to 0) **ALLOW** '**two** electrons transferred from magnesium to copper **Examiner's Comments** This type of question in the past has proved difficult but the current cohort found little difficulty. By far, the most common error was to use changes in oxidation numbers as the basis of the redox rather than using the number of electrons gained and lost for the explanation of the redox process.

		ii	Mg(s) + 2H$_2$O(l) ◊Mg(OH) $_2$(aq) + H$_2$(g) Correct reactants and products ✓ Balance and state symbols ✓	2	**ALLOW** multiples **ALLOW** Mg(OH)$_2$(s) **ALLOW** Mg(s) + H$_2$O(g) **OR** H$_2$O(l) MgO(s) + H$_2$(g) including state symbols for **one** mark **Examiner's Comments** The equation for the reaction between magnesium and water was well known – but many erroneously assumed MgO was formed.
	c	i	Ca(OH)$_2$ **OR** Calcium hydroxide **OR** CaO **OR** Calcium oxide ✓ 1	1	**ALLOW** Calcium carbonate **OR** CaCO$_3$ **Examiner's Comments** The unusual equation involving P4 molecules was answered well. Weaker candidates assumed that phosphorus was monatomic and consequentially lost credit.
		ii	6Ca + P$_4$ ◊ 2Ca$_3$P$_2$ ✓	1	**ALLOW** multiples **IGNORE** state symbols **Examiner's Comments** This potentially difficult dot-and-cross diagram of the ions present was done well by candidates.
		iii	 Ca with 8 (or no) electrons AND phosphide ion with dot-and-cross outermost octet ✓ Three Ca ions **AND** two phosphide ions with correct charges ✓	2	For first mark: If 8 electrons are shown on the cation then the extra electron in the anion must match the symbol chosen for the electrons in the cation. **IGNORE** inner shells **IGNORE** circles **ALLOW** one mark if both electron arrangements and charges are correct but only one of each ion is drawn. **ALLOW** (brackets not required) 3[Ca^{2+}] 3[Ca] $^{2+}$ [Ca^{2+}]$_3$ 2[P^{3-}] 2[P]$^{3-}$ [P^{3-}]$_2$ **DO NOT ALLOW** [Ca$_3$]$^{2+}$ [3Ca]$^{2+}$ [Ca]$^{32+}$ [P$_2$]$^{3-}$ [2P]$^{3-}$ [P]$_2$
			Total	**10**	

93		i	SF_6 **AND** Sulfur(**VI)** fluoride **OR** Sulfur **hexa**fluoride ✓	1	**IGNORE** sulfur fluoride **Examiner's Comments** Nearly all candidates knew the formula of the molecule in question but some of these were less secure when it came to the name. Sulfur(IV) fluoride being the most common error.
94		ii	$2F_2 + 2NaOH$ ◊$F_2O + 2NaF + H_2O$ M1 F_2O AND NaF ✓ M2 Rest of equation (including balance) ✓	2	**ALLOW** multiples **IGNORE** state symbol **ALLOW** OF_2 for F_2O **AND** FNa for NaF **ALLOW** both marks for alternative equations which have both F_2O and NaF **AND** three products Eg $3F_2 + 2NaOH$ ◊$2F_2O + 2NaF + H_2$ Eg $2F_2 + NaOH$ ◊$F_2O + NaF + HF$ **Examiner's Comments** Even weaker candidates coped well with the construction of this difficult equation. (Once again suggesting that having covered the A2 part of the specification, this had given candidates the experience that the normal AS candidate would not have met.)
			Total	**3**	
94			M1 *Mixing of first pair of solutions* Adding (aqueous) barium chloride to bromine (water) **OR** $BaCl_2 + Br_2$ M2 *Mixing of second pair of solutions* Adding (aqueous) calcium iodide to bromine (water) **OR** $CaI_2 + Br_2$ **OR** Adding aqueous magnesium bromide to aqueous iodine **OR** $MgBr_2 + I_2$	5	For M1 and M2 **ALLOW** any halide for the named halides in the question eg 'potassium chloride' for barium chloride 'potassium bromide' **DO NOT ALLOW** 'barium chlorine/BaCl' 'calcium iodine/CaI' 'magnesium bromine/MgBr' as the halide **DO NOT ALLOW** 'bromide' for 'bromine' **OR** 'iodide' for 'iodine' M1 can be seen anywhere M2 could be awarded from a correct ionic equation in M4 M2 can be seen anywhere If both M2 tests and M1 are given, this will nullify M5 M3 is given for the correct resultant colour of pairs of solution given in M1 and M2. If both possible pairs of solutions in M2 are given, both colours must be correct. **IGNORE** colours of other combinations of solutions **IGNORE** colours in the aqueous layer if

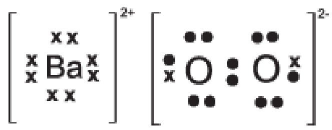
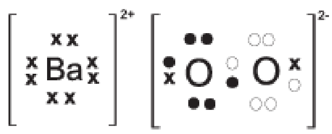
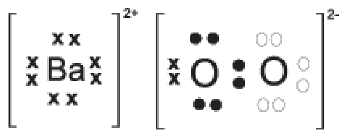
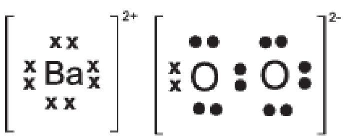
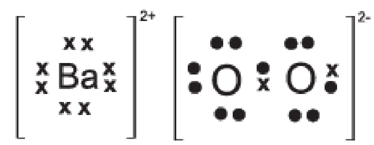
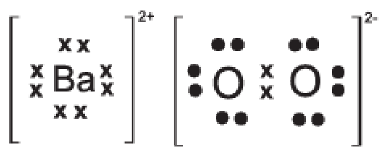
					stated
			M3 Colours in cyclohexane Colour for M1 is orange **OR** yellow **AND** Colour for M2 is purple **OR** violet **OR** mauve **OR** pink **OR** lilac *M4 Ionic equation mark* $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ *M5 Use of M1 and **one** of M2 as only two experiments*		**DO NOT ALLOW** other colours for M1 and M2 (eg iodine is brown) M4 can be awarded anywhere M4 also scores M2 if not already awarded **ALLOW** multiples **IGNORE** state symbols **IGNORE** $I_2 + 2Br^- \rightarrow I_2 + 2Br^-$ **IGNORE** $Br_2 + 2Cl^- \rightarrow Br_2 + 2Cl^-$ **DO NOT ALLOW** other ionic equations **DO NOT ALLOW** if more than two experiment are attempted even if pointless eg 'barium chloride + calcium iodide' Place the 'tick' for M5 against the sub-total mark, [5], at the bottom right hand side of the answer space **Examiner's Comments** Able candidates were able to provide full answers involving only two reactions, one ionic equation and correct colours of products in succinct form. Some candidates answered the question correctly then ignored the instruction to keep the number of reactions to a minimum and gave an unnecessary third confirmatory reaction. This question distinguished well for many weaker candidates were unable to produce chemically coherent responses. Suggestions for 'impossible' reactions such as adding magnesium bromide to calcium iodide were frequently seen from such candidates.
			Total	**5**	
95			Ga^{3+} ✓	1	**Examiner's Comments** The formula, Ga^{3+}, was almost universally known.
			Total	**1**	
96		i	More energy is required for bond breaking than is released by bond making ✓	1	**Examiner's Comments** The poor quality of answers observed surprised the Examiners as this question had featured a number of times on legacy

					papers which would have been used in Centres to prepare candidates for this examination. Many candidates were not able to explain that bond breaking requires energy whereas bond making produces energy. For the reaction to be endothermic more energy is required to break bonds than is evolved when bonds are formed. In their answers candidates frequently stated that both processes required energy or that more bonds were broken than were formed.
		ii	Enthalpy profile diagram • Δ*H* labelled **OR** 82 on vertical arrow • Products above reactants (either chemical symbols or the words products and reactants) • Arrow upwards ✓ Formulae **AND** state symbols $N_2(g) + ½O_2(g) \rightarrow N_2O(g)$ ✓	2	 **IGNORE** activation energy **DO NOT ALLOW** multiples of equation: 1 mole of N_2O is formed **Examiner's Comments** Half of the candidates scored zero for this question, many failing to label the enthalpy change or to show this as an arrow pointing upwards. Although the question stated that the activation energy was not required, candidates frequently included it in their diagrams and then labelled it ΔH. Many Candidates did not write the formula of the reactants or products and those who did multiplied the species by two so as the diagram did not represent the enthalpy of formation.
			Total	**3**	
97	a		**Equations can be in either order** $Na_2O + H_2O \rightarrow 2NaOH$ ✓ $NaFeO_2 + 2H_2O \rightarrow Fe(OH)_3 + NaOH$ ✓	2	**ALLOW** multiples throughout **IGNORE** state symbols **ALLOW** $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ **DO NOT ALLOW** equations with uncancelled species. e.g. $Na_2O + 2H_2O \rightarrow 2NaOH + H_2O$ **ALLOW** $2NaFeO_2 + H_2O \rightarrow Fe_2O_3 + 2NaOH$ **OR** $2NaFeO_2 + H_2O \rightarrow Fe_2O_3 + 2Na^+ + 2OH^-$ **Examiner's Comments**

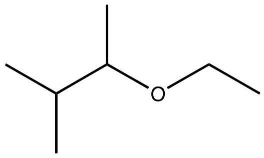
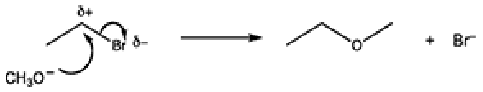
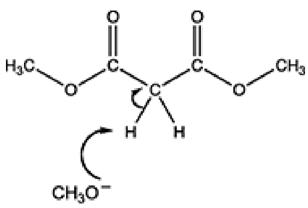
					The information needed to write the equation was within the information provided for step 1 and the stem. Candidates were much more successful with the first than the second equation. The clue that an alkaline solution had been formed should have helped with the identification of NaOH as a product of both reactions. The brown precipitate provided a clue that $Fe(OH)_3$ had been formed although the examiners also credited an equation producing Fe_2O_3.
	b		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 33.7%, award **6 marks**. **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below …………………………………………………… amount $S_2O_3^{2-}$ used = $0.1000 \times \frac{25.50}{1000}$ = **2.550 × $^{10-3}$** (mol) ? amount I_2 = 2.550 × 10^{-3} **÷ 2** **1.275 × 10^{-3}** (mol) ✓ amount CrO_4^{2-} **2/3 ×** 1.275 × 10^{-3} **OR** 1.275 × 10^{-3} **÷ 1.5** = **8.5(00) × 10^{-4}** (mol) ✓ amount CrO_4^{2-} in original 1000 cm^3 = **40 ×** 8.5(00) × 10^{-4} = **3.4(00) × 10^{-2}** mol ✓ Mass of Cr / Cr^{3+} in ore = **52.0** × 3.4(00) × 10^{-2} g **1.768 g** ✓ percentage Cr in ore = $\frac{1.768}{5.25} \times 100$ = **33.7%** ✓ **MUST** be to **one** decimal place (in the question)	6	***FULL ANNOTATIONS MUST BE USED*** **IF** a step is omitted but subsequent step subsumes previous, then award mark for any missed step **Working: at least 3 SF throughout until final % mark** BUT ignore trailing zeroes, ie for 0.490 allow 0.49 …………………………………………………… **ECF** answer above **÷ 2** **ECF** answer above **÷ 1.5** **ECF** answer above **× 40** **ECF** answer above × 52.0 **IMPORTANT**: The last two marks are **ONLY** available by using 52.0 for Cr …………………………………………………… **Common ECFs:** **0.8%** × 40 missing — 5 marks (scaling error) **0.84%** — × 40 missing 4 marks (scaling error and 2 DP) **33.68%** — 5 marks (2 DP) **16.8%** — 5 marks (divide Cr somewhere by 2) **144.9%; 72.5%** 4 marks (**Final 2 marks unavailable**) Use of $M(Fe(CrO_2)_2)$ = 223.8 instead of *M*(Cr). **Examiner's Comments** Many candidates were on firm territory

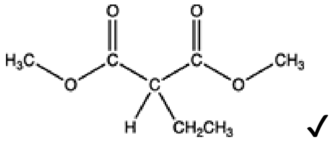
					with a redox titration problem. The majority went through a well-rehearsed sequence of steps to obtain four marks for reaching the amount of CrO_4^{2-} ions in the original solution. Sometimes, candidates used the 1:1.5 molar ratio for CrO_4^{2-} : I_2 the wrong way around to obtain 1.9125×10^{-3} rather than 8.50×10^{-4} mol CrO_4^{-4}. More candidates had problems in scaling up by 40 to obtain the original amount of CrO_4^{2-} as 3.40×10^{-2} mol. Strangely many used a factor of 4 instead. The last two marks proved to be more elusive, with many candidates calculating the percentage of $Fe(CrO_2)_2$ rather than Cr in the sample of chromite. The responses seen show just how far candidates have travelled since early structured titration calculations for AS to complex unstructured calculations at the end of the A-level course. Answer: 33.7%
	c		*Overall*: $_4^{2-} + 3I^- + 4H_2O \rightarrow Cr^{3+} + 1\frac{1}{2} I_2 + 8OH^-$ ✓ CrO *Half equations*: $_4^{2-} + 4H_2O + 3e^- \rightarrow Cr^{3+} + 8OH^-$ ✓ CrO $2I^- \rightarrow I_2 + 2e^-$ ✓	3	**ALLOW multiples and equilibrium signs throughout** **IGNORE** state symbols throughout e.g. $2CrO_4^{2-} + 6I^- + 8H_2O \rightarrow 2Cr^{3+} + 3I_2 + 16OH^-$ **ALLOW** equation using H^+. i.e. $CrO_4^{2-} + 3I^- + 8H^+ \rightarrow Cr^{3+} + 1\frac{1}{2} I_2 + 4H_2O$ **OR** $2CrO_4^{2-} + 6I^- + 16H^+ \rightarrow 2Cr^{3+} + 3I_2 + 8H_2O$ **ALLOW** CrO_4^{2-} half equation using H^+. i.e. $CrO_4^{2-} + 8H^+ + 3e^- \rightarrow Cr^{3+} + 4H_2O$ **Examiner's Comments** This part required candidates to construct three equations for an unfamiliar reaction. The examiners allowed equations using H^+ rather than OH^-. It was then possible to credit many candidates with the full three marks with many excellent responses seen. Predictably the equations involving CrO_4^{2-} were more difficult but even some weaker candidates were able to construct an equation for the oxidation of iodide ions. The very best

					candidates did manage to construct the equations in alkaline conditions.
			Total	**11**	
98			$C_{12}H_{25}$ ✓	1	**IGNORE** $C_{24}H_{50}$ **Examiner's Comments** The majority of candidates were able to deduce the correct empirical formula of the alkane.
			Total	**1**	
99			$2Al + 3F_2 \rightarrow 2AlF_3$ ✓	1	**ALLOW** multiples **IGNORE** state symbols **Examiner's Comments** Although the formula of AlF_3 was not given, this question was well answered. When the mark was not awarded it was rarely because of errors in the formula for AlF_3, but more in the ratio of the reactants or in fluorine not being given as diatomic. Occasionally, the symbol for fluorine was given as Fl.
			Total	**1**	
100		i	**Reaction 1:** $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$ ✓ **Reaction 2:** $Ba_3N_2 + 6H_2O \rightarrow 3Ba(OH)_2 + 2NH_3$ Correct products ✓ Balancing ✓	3	Ignore state symbols **Examiner's Comments** Both equations were relatively challenging. Reaction 1 was a direct question about reactions of Group 2 elements. Reaction 2 demanded a higher level of application based upon information given. Many identified the alkaline gas as NH3, but then incorrectly assumed that the alkaline solution was BaO instead of $Ba(OH)_2$. Weaker candidates suggested equations with hypothetical species that could not have born any relation to formulae that they might have encountered before.
		ii	Giant ionic (lattice) ✓	1	**ALLOW** ‘Giant lattice with ionic bonds’ **ALLOW** ‘Giant ionic bonds’ **DO NOT ALLOW** ‘atoms or molecules or dipoles’

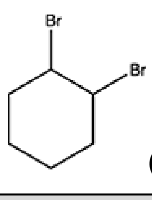
					Examiner's Comments This question was relatively well answered, although some candidates did negate the mark by referring to molecules of Ba_3N_2 either directly or by indirect reference to intermolecular forces.
		iii	 OR  OR  OR 	1	Ba must have a 2+ charge Ba can be with or without octet. **IGNORE** lack of charge on O_2^{2-} ion O_2^{2-} ion to have 12 electrons belonging to O atoms + 2 other electrons of another symbol. The 2 other electrons must match Ba if Ba has an octet. If O electrons are shown as 6 of one symbol and 6 of another, each O must have six electrons of the same symbol ALLOW  OR  **Examiner's Comments** This question was designed to be difficult, but many candidates rose to the challenge. Weaker candidates simply drew a *'dot-and-cross'* diagram for BaO_2 in which they treated each oxygen species

					as an oxide ion each having a single negative charge. Many stronger candidates did realise from the structure given in the question that there was only a single bond between the two oxygen atoms, as was clear from their suggested diagram. Only the stronger candidates managed to incorporate correctly the electrons from barium, to arrive at a correct version of the bonding of BaO_2.
			Total	**5**	
101			NH_4+ ✓ NO_3^- ✓	2	Mark incorrect ions first **Examiner's Comments** This question proved more difficult than intended. The specification indicates the polyatomic ions which the candidates are expected to know the formulae of and it was little surprising that many candidates could not make the leap from the empirical formula given to the possible ions present. Weak answers came from candidates who took their lead from the empirical formula $H_4N_2O_3$ to suggest that the ions were H^+ and $N_2O^−$. Among stronger candidates it was more common to identify $NO_3^−$ than NH_4^+, although it remained rare to see both correct ions given.
			Total	**2**	
102		i	$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ (1)	1	**allow** multiples
		ii	*Energy (into water) mark* 70.0 × 4.18 × 16.5 = 4827.9 (J) or 4.8279 (kJ) (1) *amount of substance mark* $n(H_2O) = \frac{35.0}{1000} \times 2.40 = 0.084(0)$ (mol) *$\Delta_{neut}H$ mark* (−)4.8279 / 0.084(0) = (−)57.475 **OR** (−)57.48 **OR** (−)57.5 (1) Correctly rounded to at least 3 significant figures	3	**allow** rounding to 4828 **OR** 4830 **allow** amount of substance mark to be based upon either HC*l* or NaOH **allow ecf** for $\frac{\text{Energy (into water) mark}}{\text{Amount of substance mark}}$
		iii	1 mole of water had been formed (1)	1	
		iv	$\frac{2 \times 0.5}{16.5} \times 100 = 6\%$ (1)	1	
			Total	**6**	

103			A/Br_3	1	
			Total	**1**	
104	a		 ✓	1	
	b	i	$2Na + 2CH_3OH \rightarrow 2Na^+ + 2CH_3O^- + H_2$ ✓	1	**ALLOW** $2Na + 2CH_3OH \rightarrow 2CH_3ONa + H_2$
		ii	 Curly arrow from CH_3O^- to carbon atom of C-Br bond ✓ Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$ **AND** curly arrow from C–Br bond to the Br atom ✓ Products of reaction (must not be ambiguous) ✓	3	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous. The curly arrow must start from **O atom** of CH_3O^- **AND** must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge. **ALLOW** S_N1 Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, and curly arrow from C–Br bond to the Br atom. Correct carbocation drawn. **AND** curly arrow from CH_3O^- to carbocation. The curly arrow must start from the oxygen atom of the CH_3O^-, and must start either from a lone pair or from the negative charge.
		iii	CH_3O^- donates an electron pair **AND** heterolytic fission ✓	1	**ASSUME** 'it' refers to CH_3O^-
	c		**Chemical shift, δ/ppm** | **Relative peak area** | **Splitting pattern** 0.5−1.9 | 3 | Triplet ✓ 3.0−4.3 | 2 | Quartet ✓ 0.5−1.9 | 6 | Doublet ✓ 3.0−4.3 | 1 | Heptet ✓	4	**ALLOW** δ values ± 0.2 ppm, as a range or a value within the range **ALLOW** multiplet for heptet
	d	i	 Curly arrow from CH_3O^- to H of CH_2 ✓ Curly arrow from C–H bond to C of CH_2 ✓	3	The curly arrow must start from **O atom** of CH_3O^- **AND** must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge.

					**ALLOW** any unambiguous structure, skeletal, displayed, structural or combination.
		ii	CH_3O^- accepted a proton ✓	1	**ASSUME** 'it' refers to CH_3O^-
			Total	**14**	
105		i	$1s^22s^22p^63s^23p^63d^{10}4s^1$ ✓	1	**ALLOW** upper case S, P and D and subscripts, e.g. ……$3S_23P_63D_{10}$ **ALLOW** $4s^1$ before $3d^{10}$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$, i.e. **DO NOT ALLOW** $[Ar]3d^{\mathbf{8}}$ Look carefully at $1s^22s^22p^63s^23p^6$ − there may be a mistake
		ii	$n = \frac{95.0}{24000} = 3.96 \times 10^{-3}$ (mol)✓ *Calculation of M* $M = \frac{m}{n} = \frac{254 \times 10^{-3}}{3.96 \times 10^{-3}} = 64.2$ OR 64.1 (g mol^{-1})✓ *Gas*: sulfur dioxide **OR** SO_2 ✓ *Equation* $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$ ✓	4	**IF there is an alternative answer, check to see if there is any ECF credit possible using working below** Unrounded values give 64.2; Rounded to 3 SF gives 64.1 **ALLOW** $Cu + 2H^+ + H_2SO_4 \rightarrow CU^{2+} + SO_2 + 2H_2O$
			Total	**5**	
106	a		2,3,5-trimethyloctane	1	This is the **only** acceptable response
	b	i	**FIRST CHECK THE ANSWER ON THE ANSWER LINE IF** answer = 3.88×10^5 (m^3) award all five marks *Calculating moles of $C_{11}H_{24}$* (moles$=\frac{80.4 \times 10^6}{156}$) = 515385 *Use of stoichiometry to calculate moles of CO_2* (11 × 515385) = 5669231 *Rearranging ideal gas equation to make*	5	Allow any correctly rounded value from 515000 to calculator value of 515384.6154 Allow any correctly rounded value from 5670000 to calculator value of 5669230.769

			V subject **AND** *conversion to Pa and K* $V = \frac{nRT}{P} = \frac{5669231 \times 8.314 \times 218}{26.5 \times 10^3}$ 3.88×10^5 (m^3) Correct answer correctly rounded Given in standard form **AND** to 3SF		**ALLOW ECF** from incorrect moles, pressure or temperature (in K). **Common incorrect answers are shown below** **Award 4 marks for** 3.88×10^{-1} (using 80.4 g in moles calculation) 3.88×10^8 (using 26.5 Pa as pressure)3.52×10^4 (using moles $C_{11}H_{24}$ as moles of CO_2) **DO NOT ALLOW** marking points 3, 4, and 5 for responses which have a negative value for volume of CO_2 (temperature not converted to K). i.e. max 2
		ii	$N_2 + O_2 \rightarrow 2NO$	1	**ALLOW** multiples
			Total	**7**	
107	a	i	$Sr(s) + 2H_2O(l) \rightarrow Sr(OH)_2(aq) + H_2(g)$ **Note: all** state symbols required	1	**allow** multiples
		ii	$n(Sr) = n(Sr^{2+}) = 0.200 / 87.6 = 2.28 \times 10^{-3}$ (1) $[Sr^{2+}] = 2.28 \times 10^{-3} \times 1000 / 250 = 9.13 \times 10^{-3}$ (mol dm^{-3}) (1)	2	**allow ecf**
		iii	Greater volume with Ca **AND** larger amount / more moles of Ca **OR** A_r Ca is smaller (1) $n(Ca) = 0.200/40.1 = 0.005(0)$ (mol) (1) volume H_2 with Sr = 55 cm^3 **AND** volume with Ca = 120 cm^3 **OR** 65 cm^3 more H_2 with Ca (1)	3	**ora** **allow** values up to calculator values **allow** volumes ± 1 cm^3
	b		$Cl(g) \rightarrow Cl^+ (g) + e^-$ Correct species, balanced **AND** correct state symbols	1	**allow** $Cl(g) - e^- \rightarrow Cl^+(g)$ **ignore** state symbols after electron
	c		**Group**: 2 (1) **Justification**: Large increase between 2nd and 3rd ionisation energy values. (1)	2	**allow** alkaline earth **No ecf** for justification (dependent on correct group)
			Total	**9**	

108			**A**: Sc^{3+} **B**: S^{2-}	2	
			Total	**2**	
109		i	$2NH_3 + NaOCl \rightarrow N_2H_4 + NaCl + H_2O$	1	
		ii	 (1) Bond angle 107° (1)	2	diagram must attempt to show geometry around the nitrogen atom to be pyramidal. **allow** 106–108°
			Total	**3**	
110	a		Aliphatic = E, H, I, J (1) Alicyclic = E, H, J (1) Aromatic = F, G (1)	3	
	b		C_nH_{2n+1}	1	**do not allow** C_nH_{2n+} 1
	c	i	*Equation:* $C_6H_{12}O \rightarrow C_6H_{10} + H_2O$ (1) *Calculation:* **FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 32.7 (%) award 3 marks theoretical yield = 7.65 / 100 = 0.0765 (mol) (1) actual yield = 2.05 / 82 = 0.025 (mol) (1) % yield = (0.025 / 0.0765) × 100% = 32.7(%) (1)	4	**ignore** state symbols **allow** $C_6H_{11}OH$ for $C_6H_{12}O$ **If there is an alternative answer, check to see if there is any ECF credit possible using working below** % yield **must** be to 1 dp **allow** theoretical and actual yield calculated in mass theoretical yield = 0.0765 × 82 = 6.273 g % yield = (2.05 / 6.273) = 32.7(%) **allow ecf** from calculated actual and theoretical yields
		ii	bromine water is decolourised (1)  (1)	2	**allow** bromine water turns colourless **ignore** 'goes clear' **allow** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above
			Total	**10**	
111		i	$Ag^+ + Cl^- \rightarrow AgCl$ **OR** $Ag^+ + Br^- \rightarrow AgBr$ **OR** $Ag^+ + I^- \rightarrow AgI$	1	
		ii	Bond enthalpy decreases C−Cl > C−Br > C−I	1	**allow** chlorine–carbon bonds are strongest.
		iii	Heat the test tubes in a water bath.	1	

			Total	**3**	
112			C	1	
			Total	**1**	