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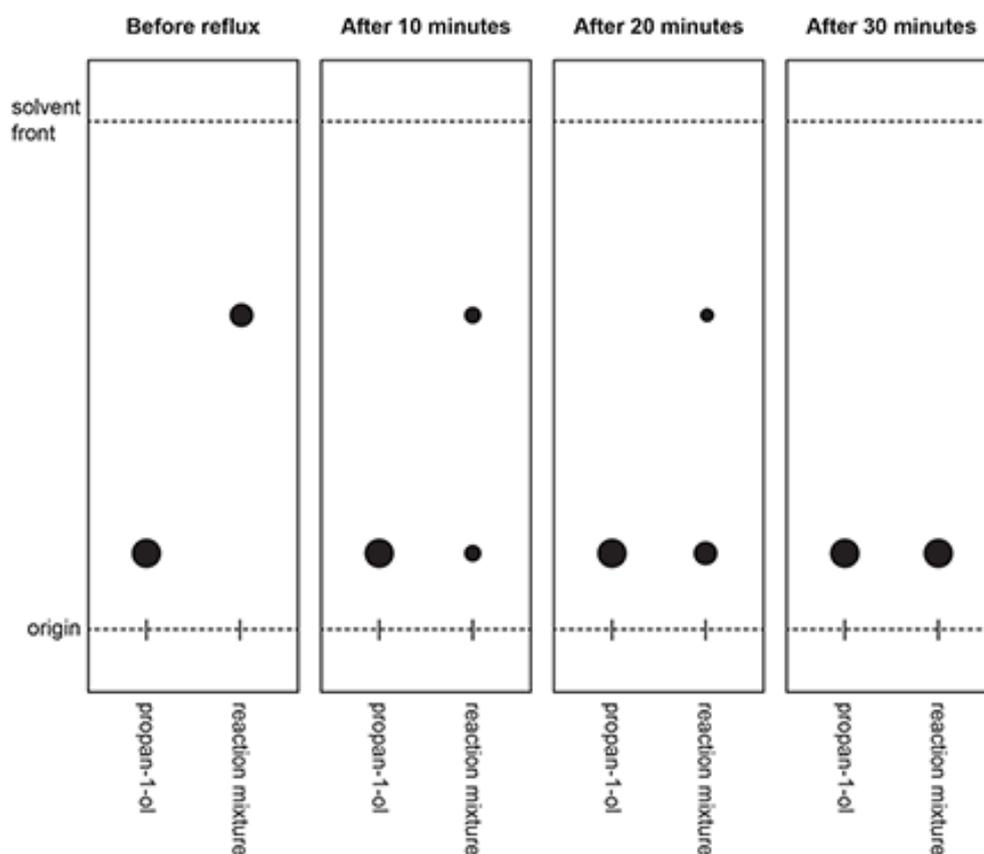
i.   Determine the R_f value of propan−1−ol.

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.

Compound G

Compound H

boiling point $= 222\,°C$
density $= 1.174\,g\,cm^{-3}$
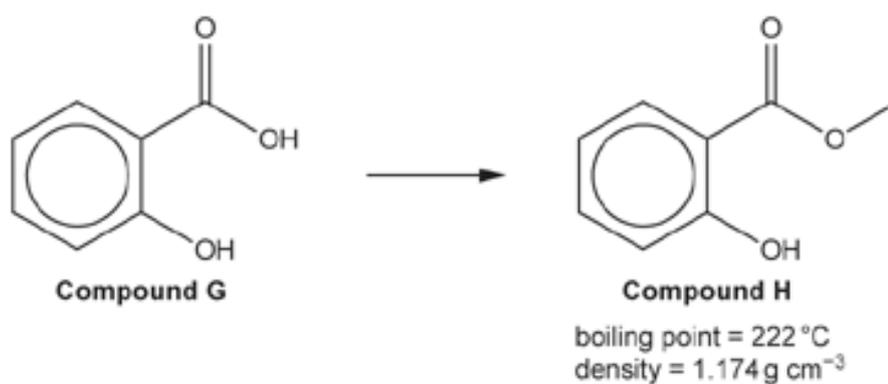
A student prepares a sample of compound **H** by the method below.

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**
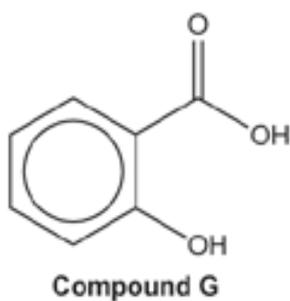
Compound G

[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
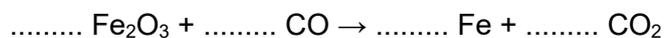
[1]

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

```
┌─────────────────────────┐
│         Barium          │
└─────────────────────────┘
            │
       Reaction 1
            ▼
┌─────────────────────────┐
│      Barium oxide       │
└─────────────────────────┘
            │
       Reaction 2
            ▼
┌─────────────────────────┐
│    Barium hydroxide     │
└─────────────────────────┘
            │
       Reaction 3
            ▼
┌─────────────────────────┐
│     Barium chloride     │
└─────────────────────────┘
```
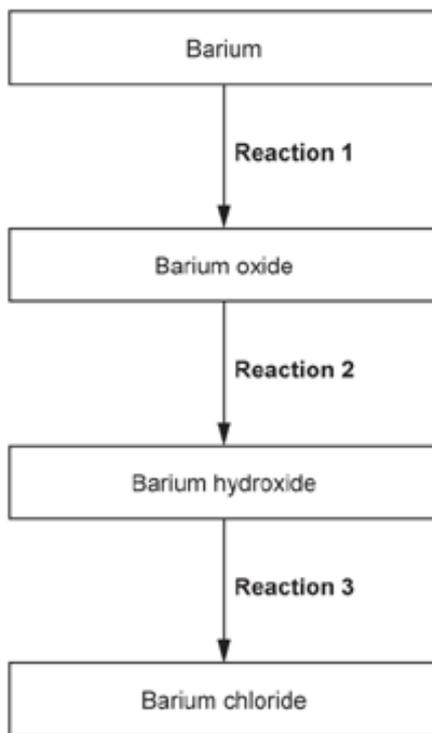
• Write balanced equations for **Reaction 1** and **Reaction 2**.
• Identify the type of reaction in **Reaction 3**.

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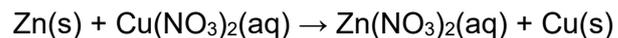
$Zn(s) + Cu(NO_3)_2(aq) \rightarrow Zn(NO_3)_2(aq) + Cu(s)$ $\qquad\qquad \Delta_r H$ $\qquad$ **Equation 3.1**

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 Δ_rH, 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 Δ_rH.

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_____**[6]**

(b). The student modifies the experiment using 50 cm³ instead of 100 cm³ 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.
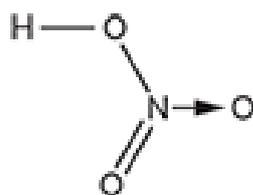
Predict the H–O–N and O–N–O bond angles in nitric acid.

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 $X_2 Y(ZO_4)_2 \cdot 6H_2O$.

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

* X^+ can be an ion of the Group 1 elements K, Rb, Cs or Fr, or an ammonium ion.
* 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.
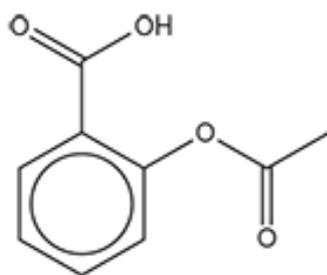
Aspirin

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.
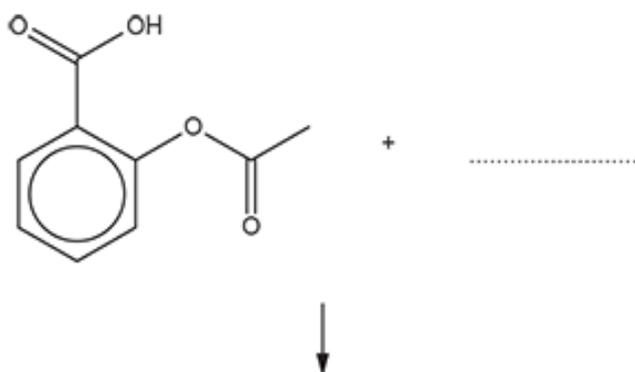
[3]

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 cm^3 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 cm^3 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.

$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g) \; \Delta H = -746 \; kJ \; mol^{-1}$
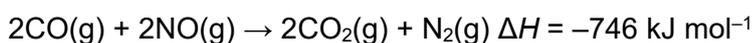
Complete the enthalpy profile diagram in **Fig. 23.1** for this reaction.

On your diagram:

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

enthalpy

progress of reaction

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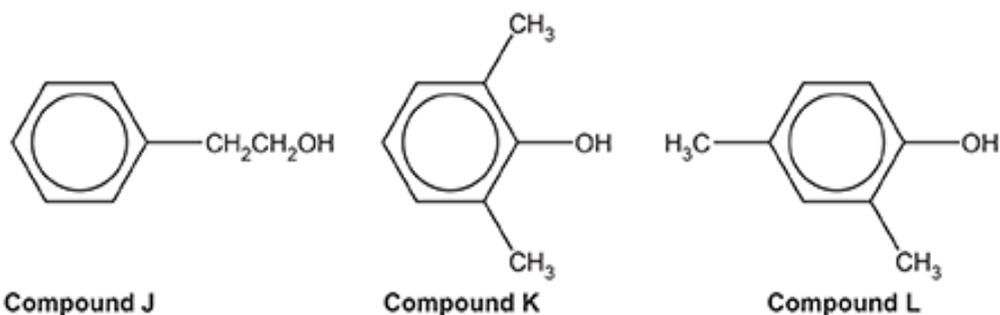
Compound **J**, $C_6H_5CH_2CH_2OH$, is reacted with acidified potassium dichromate(VI) under reflux to form organic product **M**.

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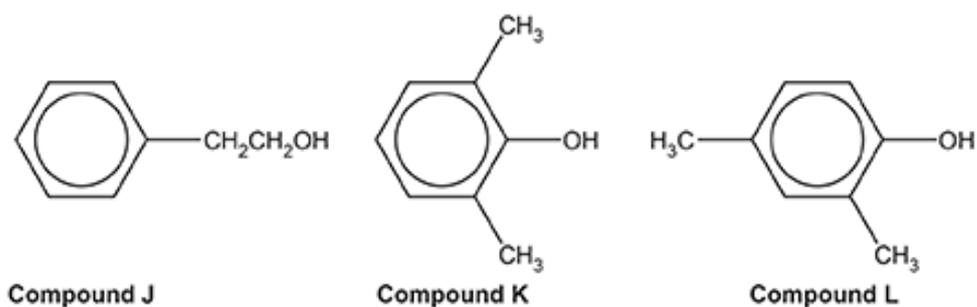
A two-stage synthesis of an amine from compound **J** is shown below.

i.   Add the reagents for each stage of this synthesis.
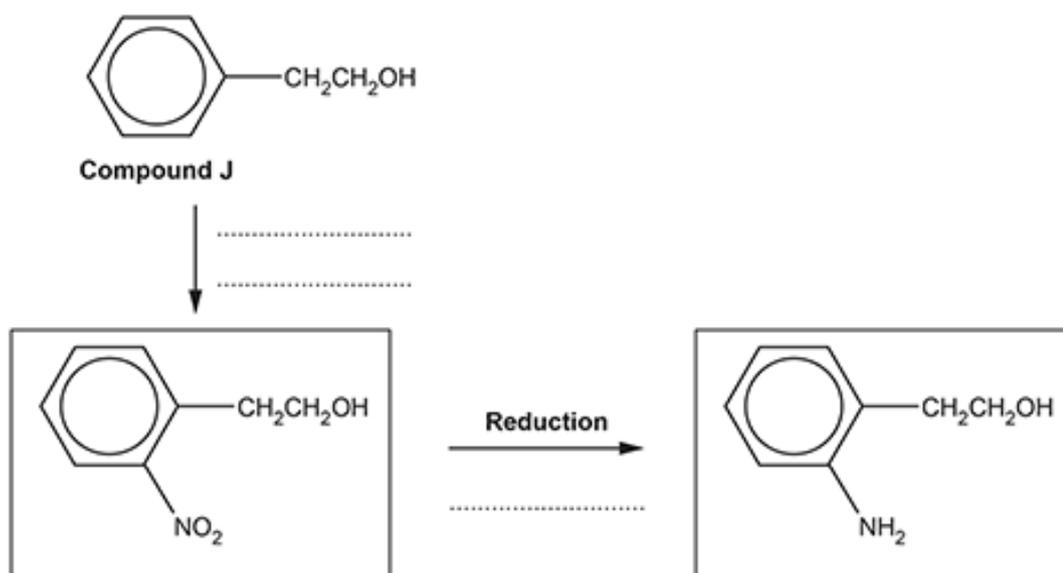
[2]

ii.   Fill in the equation for the reduction stage of this synthesis.
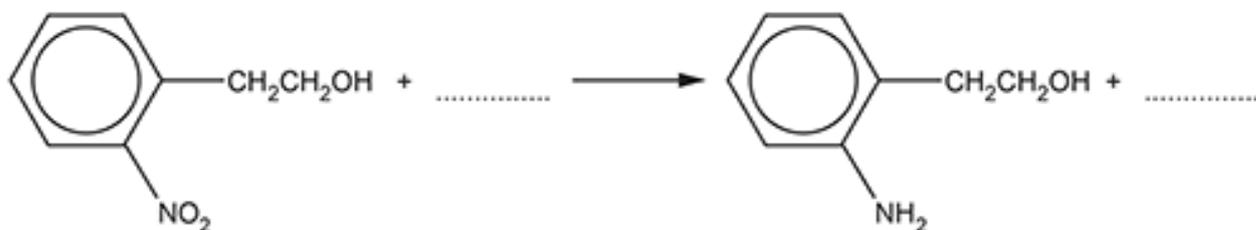
[1]

(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 NaC*l*O.

  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**Cl
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^{e}/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

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[4]

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

Experiment 1

Hydrochloric acid, $HCl(aq)$, 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 cm³ 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.

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

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[3]

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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

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[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]

END OF QUESTION PAPER