1. Which reagent would exactly neutralise 100 cm^3 of 1.00 mol dm^{-3} $H_2SO_4(aq)$?

A. 0.100 mol $Al(OH)_3$
B. 0.100 mol NH_3
C. 0.100 mol $Ba(OH)_2$
D. 0.100 mol NaOH

Your answer ☐

[1]

2. A student prepares a standard solution and carries out a titration.
The standard solution is placed in the burette.

Which of the following would result in a titre that is larger than it should be?

1: Water is added to completely fill the volumetric flask, rather than to the graduation line.

2: The conical flask is washed out with water before carrying out each titration.

3: The pipette is washed out with water before carrying out each titration.

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

Your answer ☐

[1]

3. The equation for the reaction of aqueous phosphoric(V) acid, H_3PO_4, with aqueous sodium hydroxide, NaOH(aq) is shown below.

$$H_3PO_4(aq) + 3NaOH(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$$

25.0 cm^3 of a 0.200 mol dm^{-3} $H_3PO_4(aq)$ is titrated with 0.600 mol dm^{-3} NaOH(aq).

Which statement is correct?

A. The end point occurs when 25.00 cm^3 of NaOH(aq) has been added.
B. The end point occurs when 75.00 cm^3 of NaOH(aq) has been added.
C. After titration the final solution contains 0.0150 mol of Na_3PO_4.
D. After titration the final solution contains 0.0150 mol of H_2O.

Your answer ☐

[1]

4. This question is about acids and bases.

Nitric acid, HNO_3, and nitrous acid, HNO_2, are two Brønsted–Lowry acids containing nitrogen.

A student measures the pH of 0.0450 mol dm^{-3} solutions of HNO_3 and HNO_2 (pK_a = 3.35) and found that the acids had different pH values.

i. Explain why the pH values are different.

....

.... **[1]**

ii. Calculate the pH value of 0.0450 mol dm^{-3} HNO_3 to **two** decimal places.

Show your working.

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

iii. Calculate the pH value of 0.0450 mol dm^{-3} HNO_2 to **two** decimal places.

Show your working.

pH = ... **[3]**

5. α-Hydroxy acids (AHAs) are naturally occurring acids often used as cosmetics.

Compound **K** is an AHA that is often used in 'chemical face peels'.

A student wishes to identify compound **K** from the list of compounds below.

glycolic acid	$HOCH_2COOH$
malic acid	$HOOCCH_2CHOHCOOH$
mandelic acid	$C_6H_5CHOHCOOH$
pantoic acid	$HOCH_2C(CH_3)_2CHOHCOOH$

The student isolates compound **K** and analyses a sample of the compound by titration.

The student dissolves 1.89 g of compound **K** in water and makes the solution up to 250.0 cm^3 in a volumetric flask. The student titrates 25.0 cm^3 of this solution with 0.150 mol dm^{-3} NaOH(aq).

18.80 cm^3 of NaOH(aq) were required for complete neutralisation.

Use the results of the student's analysis to identify compound **K** from the list above.

Show **all** of your working.

K = ... **[5]**

6. A student wants to remove an acid impurity from an organic liquid.

What should the student do?

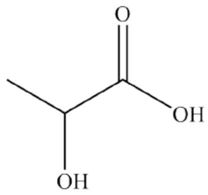
A. Add Na_2CO_3(aq)
B. Reflux the mixture
C. Add Br_2
D. Add $MgSO_4$

Your answer ☐

[1]

7. This question is about organic acids.

Lactic acid, shown below, has two functional groups.



Lactic acid reacts with bases and with many metals.

- An aqueous solution containing 1.125 g of lactic acid is reacted with an excess of magnesium producing hydrogen gas.
- The excess magnesium is removed.
  The water is evaporated, leaving a white solid, **A**.

i. Name the type of reaction of lactic acid with bases and with metals.

reaction with bases:

reaction with metals:

[1]

ii. Calculate the volume of $H_2(g)$ produced, measured at room temperature and pressure.

volume of H_2 = ... **[2]**

i. What is the empirical formula of the white solid **A**?

[1]

ii. Predict **two** reactions of lactic acid, each involving a different functional group.

Do **not** include reactions with bases or metals.

For each reaction,
- state the type of reaction, the reagents and conditions
- draw the structures of any organic products formed.

[4]

8(a). 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]**

(b). In an experiment, a scientist prepared a 0.500 g sample of a salt made by neutralisation.

Analysis of the sample gave the following data.

Element	**Mass present / g**
hydrogen	0.025
oxygen	0.300
nitrogen	0.175

i. Calculate the empirical formula of the salt.

empirical formula = ... **[2]**

ii. Suggest the formula of the acid and base that the scientist used to prepare this salt.

acid: --
base: --

[1]

9(a). A student carries out a titration to determine the molar mass of an unknown acid, **A**.

- The student dissolves 2.24 g of acid **A** in distilled water and makes the solution up to 250.0 cm^3.
- The student titrates a 25.0 cm^3 portion of this solution with 0.120 mol dm^{-3} NaOH.
- 25.25 cm^3 of 0.120 mol dm^{-3} NaOH are required to reach the end point.

Name the apparatus that the student should use to

- make up the acid solution to 250.0 cm^3
- measure the 25.0 cm^3 portion of acid solution.

make up the acid solution to 250 cm^3: --

measure the 25.0 cm^3 portion: --

[1]

(b). The acid reacts with NaOH in a 1 : 1 molar ratio.
Calculate the molar mass of acid **A**.

molar mass of acid **A** = ... g mol^{-1} **[3]**

(c). The student is not confident that their titre is accurate.
Suggest what the student should do next to reduce the effect of any random error in the titration.

[2]

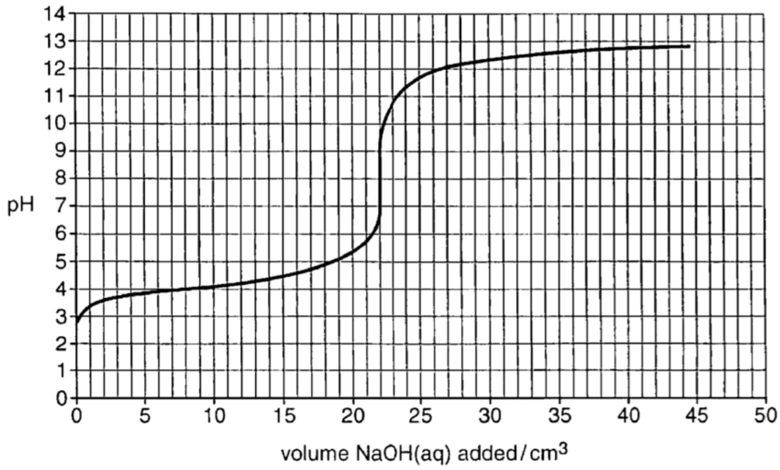
10(a). This question is about different weak acids.

A student carries out a titration to determine the concentration of a solution of ethanoic acid.

The method is outlined below.

- A 25.0 cm^3 sample of $CH_3COOH(aq)$ is pipetted into a conical flask.
- The $CH_3COOH(aq)$ is titrated by adding 0.125 mol dm^{-3} NaOH from a burette.
- The pH of the solution is measured continuously, with stirring, as the NaOH(aq) is added.

The pH titration curve is shown below.



i. How could the student measure the pH continuously as the NaOH(aq) is added?

[1]

ii. Determine the unknown concentration, in mol dm^{-3}, of the $CH_3COOH(aq)$.
Show your working.

concentration of $CH_3COOH(aq)$ = ...mol dm^{-3} **[2]**

(b). The table shows the pH ranges of four indicators.

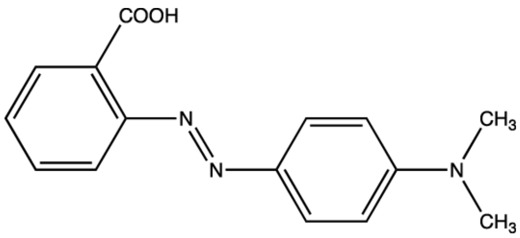
Indicator	congo red	methyl red	brilliant yellow	alizarin yellow R
pH range	3.0–5.0	4.4–6.2	6.6–7.8	10.1–12.0

i. Choose, with a reason, the indicator from the table that is most suitable for the student's titration in **(a)**.

[1]

ii. An indicator is a weak acid, HA, which has a different colour from its conjugate base, A^-.

For methyl red, the HA form is red and the A^- form is yellow.
The structure of methyl red is shown below.



methyl red

Draw the structure of the conjugate base of methyl red and explain, in terms of equilibrium, the colours of methyl red at low pH, at high pH, and at the end point of a titration. You can use HA and A^- in your explanation.

explanation: --

-- **[4]**

11. Calcium phosphate(V), $Ca_3(PO_4)_2$, is a salt used in fertilisers.

Calcium phosphate(V) can be prepared by reacting together an acid and a base.

i. Suggest the **formula** of the acid used to prepare $Ca_3(PO_4)_2$.

-- **[1]**

ii. **Name** a base which could be used to prepare $Ca_3(PO_4)_2$.

-- **[1]**

12. Cerium behaves as a typical metal when it reacts with dilute sulfuric acid to form the salt cerium(III) sulfate and a second product.

i. Identify the second product.

[1]

ii. Write the formula of cerium(III) sulfate and, explain what has happened to the cerium in this reaction in terms of the number of electrons transferred.

Formula ....

Explanation
....

[2]

iii. How has a salt been formed in this reaction?

[1]

13(a). A student was given 200 cm^3 of solution **X** in which sodium hydroxide, NaOH, and sodium hydrogencarbonate, $NaHCO_3$, had **both** been dissolved.

The student carried out **two different** titrations on samples of solution **X** using 0.100 mol dm^{-3} sulfuric acid, H_2SO_4.

- In the first titration, **both** NaOH **and** $NaHCO_3$ were neutralised.
- In the second titration, **only** NaOH was neutralised.

The student's results for the titrations of 25.0 cm^3 samples of solution **X** are shown.

volume of H_2SO_4 needed to neutralise **both** NaOH **and** $NaHCO_3$	29.50 cm^3
volume of H_2SO_4 needed to neutralise **only** NaOH	18.00 cm^3

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$
$$2NaHCO_3(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$$

i. Calculate the amount, in mol, of H_2SO_4 used to neutralise **only** the NaOH in 25.0 cm^3 of solution **X**.

Amount = ... m

ii. Calculate the concentration, in mol dm^{-3}, of NaOH in solution **X**.

Concentration = ... mol dm

(b).

i. Calculate the amount, in mol, of $NaHCO_3$ in the 200 cm^3 of solution **X**.

Amount = ... m

ii. Calculate the mass of $NaHCO_3$ in the 200 cm^3 of solution **X**.

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

Mass = ... g **[1]**

14(a). Calcium hydroxide is both a base and an alkali. Refer to any relevant ions in your answer.

Explain what is meant by the terms *base* and *alkali*.

Base ....

Alkali ....

[2]

(b). A student prepares a solution of calcium nitrate from calcium carbonate.

What reagent would the student need to use?

Write the equation for the reaction.

Reagent ....

Equation ....

[2]

15(a). A student investigates the reaction between strontium carbonate and dilute nitric acid.

$$SrCO_3 + 2HNO_3 \rightarrow Sr(NO_3)_2 + CO_2 + H_2O$$

The rate of reaction is determined from the loss in mass over a period of time.

i. Explain why there is a loss in mass during the reaction.

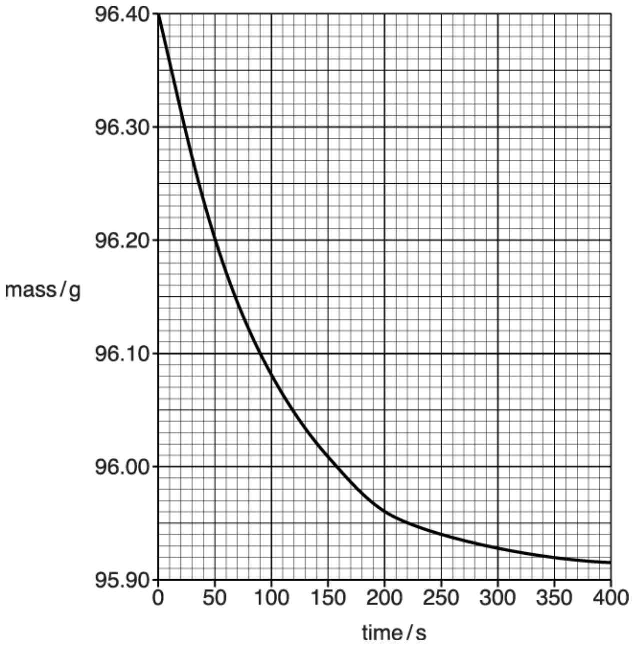
[1]

ii. An excess of strontium carbonate, $SrCO_3$, is mixed with 20.0 cm^3 of 1.25 mol dm^{-3} nitric acid, HNO_3.

Calculate the mass of $SrCO_3$ that reacts with the HNO_3.

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

(b). The student plots a graph of total mass (reagents + container) against time.



i. Describe and explain the change in the rate of the reaction during the first 200 seconds of the experiment.

[2]

ii. Using the graph, calculate the rate of reaction, in g s^{-1}, at 200 seconds.

Show your working on the graph.

rate of reaction = ... g s^{-1} **[2]**

(c). Outline a method that could be used to obtain the results that are plotted on the graph.

Your answer should include the apparatus required and the procedure for the experiment.

[3]

16. 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]

17. Which equation is **not** a neutralisation reaction?

A $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$

B $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

C $K_2CO_3(s) + 2HNO_3(aq) \rightarrow 2KNO_3(aq) + H_2O(l) + CO_2(g)$

D $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$

Your answer

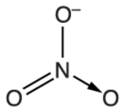
[1]

18. Nickel(II) nitrate, $Ni(NO_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

i. Write the equation for this reaction.

[1]

ii. $Ni(NO_3)_2$ contains the NO_3^- ion. The nitrogen atom bonds to the oxygen atoms with a single covalent bond, a double covalent bond and a dative covalent bond, as shown below.



Draw the '*dot-and-cross*' diagramfor the NO_3^- ion, showing outer shell electrons only.
Use a different symbol for the extra electron.

[2]

19(a). There are several isomeric alcohols with the formula $C_5H_{11}OH$.

Pentan-1-ol, $CH_3(CH_2)_3CH_2OH$, can be prepared in the laboratory by the reduction of an aldehyde.

State a suitable reducing agent for this reaction and write an equation to show the preparation of pentan-1-ol.
Use [H] to represent the reducing agent in the equation.

Reducing agent ....

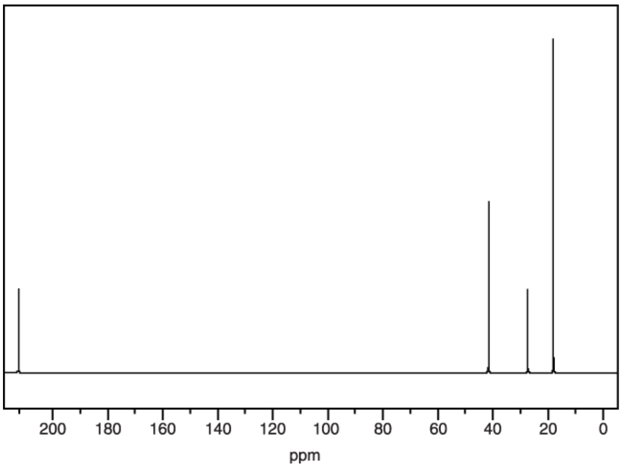
Equation ....
[2]

(b). Compound **F** is a structural isomer of $C_5H_{11}OH$.

Compound **F** is converted to compound **G** when heated under reflux with acidified potassium dichromate(VI) solution.

Compound **G** reacts with 2,4-dinitrophenylhydrazine to form an orange solid but compound **G** does not react with Tollens' reagent.

The ^{13}C NMR spectrum of compound **G** is shown below.



Compound **H** is a carboxylic acid. In a titration, 0.211 g of carboxylic acid **H** requires 22.8 cm^3 of 0.125 mol dm^{-3} NaOH for neutralisation.

Compound **F** reacts with compound **H** in the presence of concentrated sulfuric acid to form organic compound **I**.

Identify compounds **F**, **G**, **H** and **I** and draw their structures in the boxes below.

Show your working **only** for the identification of compound **H**.

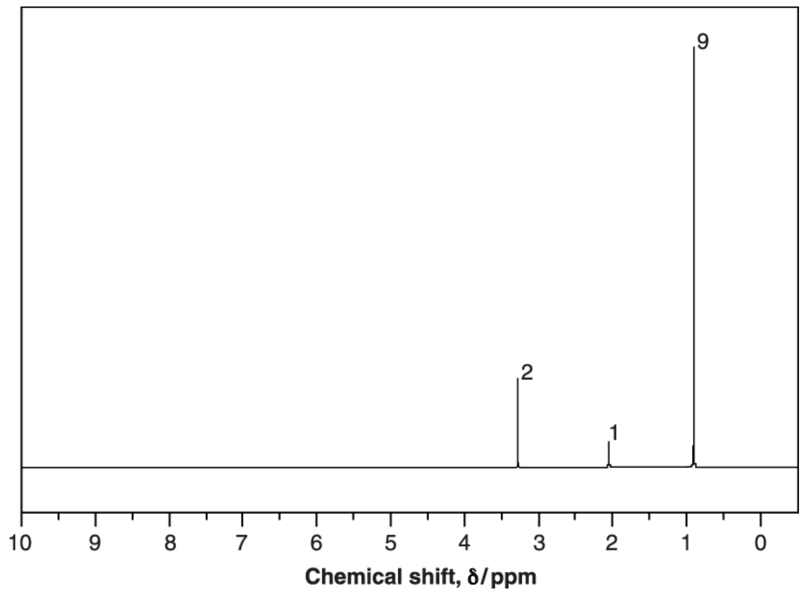
F	**G**
H	**I**

[7]

(c). Compound **J** is another structural isomer of $C_5H_{11}OH$.

The [1]H NMR spectrum of **J** is shown below.

The numbers next to each peak are the relative peak areas.



Identify compound **J** and draw its structure in the box below.

J

[1]

20(a). Hydrated copper(II) methanoate, $Cu(HCOO)_2{\bullet}xH_2O$, is a copper salt.

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

Step 1
The student prepares $Cu(HCOO)_2{\bullet}xH_2O$ 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 $Cu(HCOO)_2{\bullet}xH_2O$ 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

$Cu(HCOO)_2 \bullet xH_2O$: $1s^2$ ....

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 $Cu(HCOO)_2 \cdot xH_2O$.

Show your working.

[5]

21. 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]**

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

A garden product contains hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2{\bullet}xH_2O$. $(NH_4)_2Fe(SO_4)_2{\bullet}xH_2O$ contains 27.55% by mass of water of crystallisation.

Calculate the value of *x* in the formula $(NH_4)_2Fe(SO_4)_2{\bullet}xH_2O$.

Show your working.

x = ... **[3]**

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

- Hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2{\bullet}xH_2O$, which is soluble in water
- Crushed limestone (calcium carbonate)
- Sand.

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

[1]

ii. *Plan a procedure on a test tube scale to show that the solid mixture contains the following ions:
- NH_4^+, Fe^{2+} and SO_4^{2-} present in $(NH_4)_2Fe(SO_4)_2{\bullet}xH_2O$
- CO_3^{2-} present in crushed limestone.

Show your reasoning, including relevant equations.

[6]

23. When concentrated sulfuric acid is added to water, dissociation takes place in two stages.

Stage 1: $H_2SO_4 \rightarrow H^+ + HSO_4^-$

Stage 2: $HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$

i. 0.100 mol dm^{-3} sulfuric acid has a pH of 0.96.

Explain this observation. Your answer should include a calculation.

[3]

ii. A student adds an excess of aqueous sodium carbonate to dilute sulfuric acid.
- Predict what the student would observe.
- Explain what happens to the equilibrium in **Stage 2** as the aqueous sodium carbonate is added.

Observation ....

Explanation ....

[2]

24. Fruit juice contains a mixture of organic acids.

*Acid **C** is an aliphatic organic acid present in fruit juice.

Information about acid **C** is shown below:

- 1.21×10^{-2} mol **C** has a mass of 2.323 g.
- The molecular formula of **C** is $C_xH_yO_7$.
- 1 mol of acid **C** requires 3 mol NaOH for neutralisation.
- Acid **C** contains a hydroxyl group but produces no colour change with hot acidified dichromate(VI).
- The ^{13}C NMR spectrum of **C** has four peaks.

Analyse this information to determine the structure of acid **C**.

Show **all** your reasoning.

[6]

25. 0.0200 mol of calcium oxide is reacted completely with 2.00 mol dm^{-3} HC*l*.
What is the volume, in cm^3, of 2.00 mol dm^{-3} HC*l* required for this reaction?

A 15
B 20
C 30
D 60

Your answer

[1]

26. HA and **HB** are two strong monobasic acids.
25.0 cm^3 of 6.0 mol dm^{-3} **HA** is mixed with 45.0 cm^3 of 3.0 mol dm^{-3} **HB**.

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

A 1.9
B 2.1
C 4.1
D 4.5

Your answer [1]

27. The burette readings from a titration are shown below.

Final reading / cm^3	24.95
Initial reading / cm^3	5.00

The burette used has an uncertainty of ±0.05 cm^3 in each reading.
What is the percentage uncertainty of the resulting titre?

A 0.20%
B 0.25%
C 0.45%
D 0.50%

Your answer [1]

28. This question is about weak acids.

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

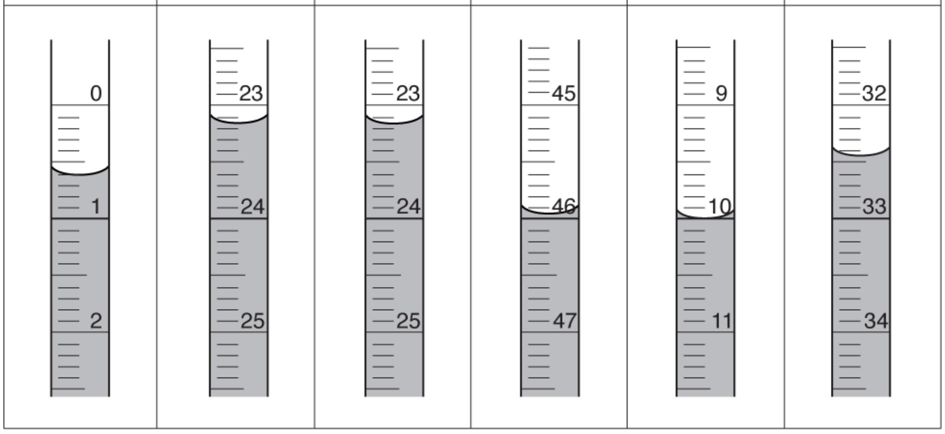
A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of **A**.

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

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

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

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

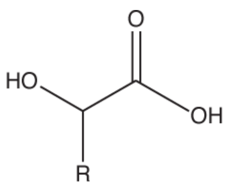


i. Record the student's readings and the titres in an appropriate format.

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

mean titre = ______________________ cm^3 **[4]**

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



compound A

Compound **A** has four optical isomers.

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

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

Show all your working.

[6]

29. Ethanoic acid, CH_3COOH, is the main dissolved acid in vinegar.

Ethanoic acid is a weak acid.
What is meant by *acid* and *weak acid*?

[1]

30. This question is about Group 2 and Group 17 (7).

Barium chloride can be prepared from barium hydroxide in a neutralisation reaction.

Write the equation for this reaction. State symbols are **not** required.

[1]

31. Solid barium chloride has a high melting point. Barium chloride dissolves in water to form a solution that can be used to test for sulfate ions.

i. Draw a '*dot-and-cross*' diagram to show the bonding in solid barium chloride.
Show outer electrons only.

[2]

ii. A solution of barium chloride can be made in the laboratory using dilute hydrochloric acid.

Suggest a compound that can be reacted with hydrochloric acid to make barium chloride.

[1]

32(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 sample of carbonate is dissolved in approximately 100 cm^3 of distilled water in a beaker and the solution transferred to a volumetric flask. The volume of the solution is made up to 250.0 cm^3 with distilled water.

Another student suggests two possible sources of error:

- A small amount of solid remained in the weighing bottle.
- A small amount of solution remained in the beaker.

State whether the other student's statements are correct.

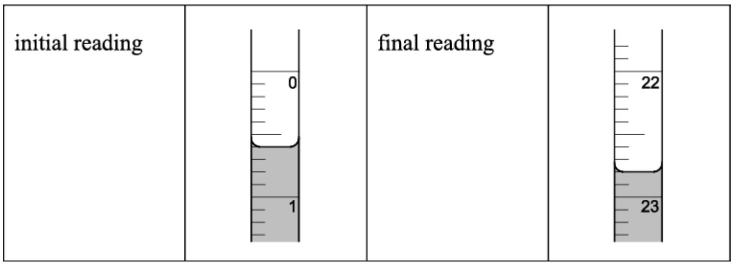
How could the procedure be improved?

-- **[2]**

(b). 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.



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]**

(c). 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]

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

The student follows the method below.

- Dissolve a weighed mass of **A** in 100 cm^3 of distilled water and make the solution up to 250 cm^3 in a beaker.
- Add the solution of **A** to a burette.
- Titrate the solution of **A** with a standard solution of sodium hydroxide, NaOH.

What is meant by the term standard solution?

[1]

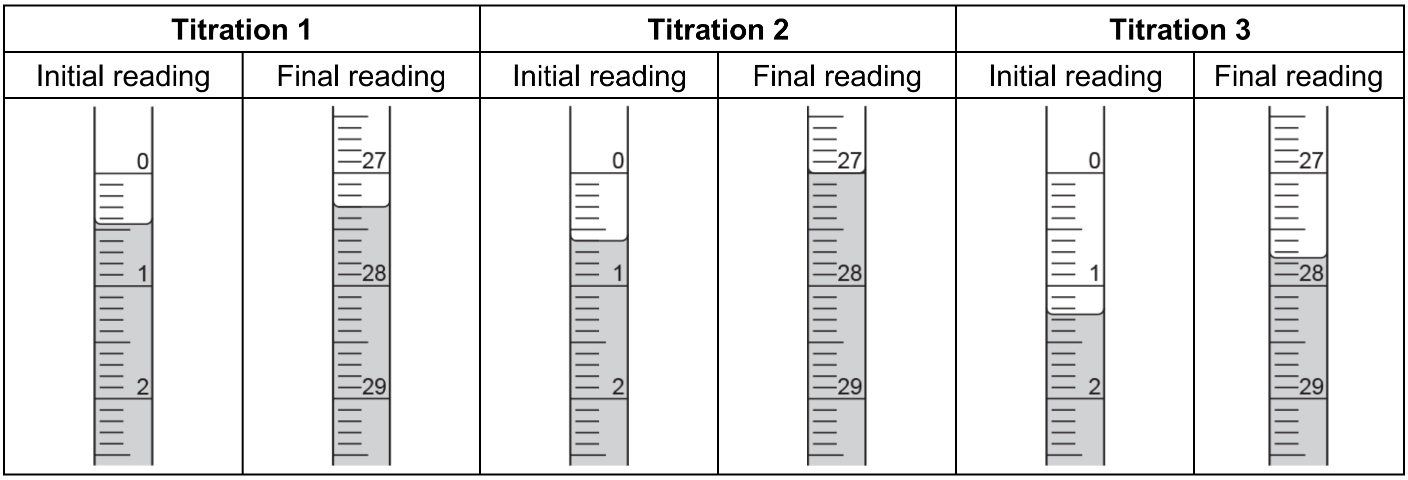
(b). Sodium hydroxide is an alkali.

What is meant by the term alkali?

[1]

(c). The student carries out a trial, followed by three further titrations.
The diagram shows the initial and final burette readings for the three **further** titrations.

The student measures all burette readings to the nearest 0.05 cm^3.



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

Calculate the mean titre, to the nearest 0.05 cm^3, that the student should use for analysing the results.

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

mean titre = ______________________ cm^3 **[4]**

ii. The uncertainty in each burette reading is ± 0.05 cm^3.

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

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

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

How should the student have made up the solution?

[1]

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

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

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

Give your answer to the nearest whole number.

Show your working.

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

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

Suggest the structure of **A**.

[1]

34. A student titrates a standard solution of barium hydroxide, $Ba(OH)_2$, with nitric acid, HNO_3.

25.00 cm^3 of 0.0450 mol dm^{-3} $Ba(OH)_2$ are needed to neutralise 23.35 cm^3 of $HNO_3(aq)$.

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

A 0.0241
B 0.0482
C 0.0900
D 0.0964

Your answer ☐ **[1]**

35. Compound **B** is an iodate(V) salt of a Group 1 metal.
The iodate(V) ion has the formula IO_3^-.

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

Step 1: The student dissolves 1.55 g of **B** in water and makes up the solution to 250.0 cm^3 in a volumetric flask.

Step 2: The student pipettes 25.00 cm^3 of the solution of **B** into a conical flask, followed by 10 cm^3 of dilute sulfuric acid and an excess of KI(aq).

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

$IO_3^-(aq) + 6H^+(aq) + 5I^-(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$

Step 3: The resulting mixture is titrated with 0.150 mol dm^{-3} $Na_2S_2O_3(aq)$.

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

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

Titration readings

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

Table 20.1

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

mean titre = ... cm^3 **[2]**

ii. The uncertainty in each burette reading is ±0.05 cm^3.

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

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

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

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

[2]

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

Show your working.

relative formula mass of **B** = ...

formula of **B** = ... **[5]**

36. Succinic acid $(CH_2COOH)_2$ is esterified by ethanol, C_2H_5OH, in the presence of an acid catalyst to form an equilibrium mixture.
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]

37. Which equation does **not** represent a neutralisation reaction?

A $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
B $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$
C $Na_2CO_3 + 2CH_3COOH \rightarrow 2CH_3COONa + CO_2 + H_2O$
D $CuO + 2HNO_3 \rightarrow Cu(NO_3)2 + H_2O$

Your answer [1]

38. This question is about compounds of magnesium and phosphorus.

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

$$3Mg(s) + 2H_3PO_4(aq) \rightarrow Mg_3(PO_4)_2(s) + 3H_2(g)$$

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

[1]

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

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

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

mass of Mg = g **[3]**

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

[2]

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

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

Formula of compound

Equation **[2]**

39(a). A student carries out a titration to determine the concentration of some hydrochloric acid.

The student titrates the hydrochloric acid against a standard solution of sodium carbonate, Na_2CO_3. The equation is shown below.

$Na_2CO_3(aq) + 2HCl\ (aq) \rightarrow 2NaCl\ (aq) + H_2O(l) + CO_2(g)$

- The student prepares 0.150 mol dm^{-3} Na_2CO_3 in a 250.0 cm^3 volumetric flask.
- The hydrochloric acid is added to a 50.0 cm^3 burette.
- The student pipettes the $Na_2CO_3(aq)$ using a 25.0 cm^3 pipette.

The student's burette readings are shown in the table.
The rough titre has been omitted.

i. Complete the table by adding the titres to the table.

Final reading / cm^3	24.60	48.45	34.30
Initial reading / cm^3	0.40	24.60	10.00
Titre / cm^3	....	....	....

[1]

ii. Calculate the mean titre of HC*l* , to the nearest 0.05 cm^3, that the student should use for analysing the results.

mean titre = ... cm^3 **[1]**

(b). Calculate the concentration, in mol dm^{-3}, of the hydrochloric acid.

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

concentration of HC*l* = ... mol dm^{-3} **[3]**

(c). In the titrations, the student measured volumes with a pipette and a burette.

- The pipette had an uncertainty of ± 0.04 cm^3 in the volume measured.
- The burette had an uncertainty of ± 0.05 cm^3 in the volume measured.

Determine whether the volume measured by the pipette or the volume measured by the burette has the greater percentage uncertainty.

[2]

40. Magnesium nitrate is used in fertilisers as a source of nitrogen.

* A student plans to prepare 250.0 cm^3 of a 0.4000 mol dm^{-3} solution of magnesium nitrate, starting from magnesium nitrate crystals, $Mg(NO_3)_2$•$6H_2O$.

Describe how the student would prepare the solution, giving full details of quantities, apparatus and method.

[6]

41. This question is about barium hydroxide.

A student carries out a titration to determine the concentration of an aqueous solution of $Ba(OH)_2$.

The student adds 25.0 cm^3 of the $Ba(OH)_2(aq)$ solution to a conical flask.
The student titrates this solution by adding 0.160 mol dm^{-3} $HNO_3(aq)$ from the burette.

The equation is shown below.

$Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(l)$

The student repeats the titration until concordant titres are obtained.

The mean titre of 0.160 mol dm^{-3} $HNO_3(aq)$ is 26.75 cm^3.

i. What is meant by concordant titres?

[1]

ii. Calculate the concentration, in mol dm^{-3}, of the $Ba(OH)_2(aq)$ solution.

concentration of $Ba(OH)_2(aq)$ = ... mol dm^{-3} **[3]**

42. 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 HCl (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]**

43. Several students titrate 25.00 cm^3 of the same solution of sodium hydroxide, NaOH(aq) with hydrochloric acid, HC*l* (aq).

One student obtains a smaller titre than the other students.

Which procedure explains the smaller titre?

A The burette readings are taken from the top of the meniscus instead of the bottom of the meniscus.
B The conical flask is rinsed with water before carrying out the titration.
C An air bubble is released from the jet of the burette during the titration.
D The pipette is rinsed with water before filling with NaOH(aq).

Your answer ☐ **[1]**

44. 20 cm^3 of 0.10 mol dm^{-3} hydrochloric acid is added to 10 cm^3 of 0.10 mol dm^{-3} sodium hydroxide.

What is the pH of the resulting mixture?

A 1.00
B 1.18
C 1.30
D 1.48

Your answer ☐ **[1]**

45. Which compound releases hydroxide ions when it dissolves in water?

A CH_3COOH
B HNO_3
C H_2SO_4
D NH_3

Your answer ☐ **[1]**

46. After delivering a solution from a pipette, a droplet remains in the tip of the pipette.

How should a student ensure that the pipette delivers the volume of solution stated on the pipette?

A Fill the pipette just above the graduation line to compensate for the volume of the droplet that remains in the tip.
B Leave the droplet in the tip.
C Shake the pipette to force out the droplet left in the tip.
D Use a pipette filler to force the droplet out of the tip.

Your answer ☐ **[1]**

47(a). Glutaric acid is used in the production of polymers.

The formula of glutaric acid can be represented as $HOOC(CH_2)_nCOOH$, where *n* is a whole number.

A student carries out a titration to find the value of *n*.

1. The student dissolves 2.891 g of glutaric acid in water and makes up the solution to 250.0 cm^3 in a volumetric flask.
2. The student transfers 25.0 cm^3 of this solution into a conical flask.
3. The student titrates the solution with 0.240 mol dm^{-3} NaOH(aq) in the burette.

Equation:
$HOOC(CH_2)_nCOOH(aq) + 2NaOH(aq) \rightarrow NaOOC(CH_2)_nCOONa(aq) + 2H_2O(l)$

The student uses phenolphthalein as the indicator.
Phenolphthalein is colourless in acid and pink in alkali.

State the colour change observed at the end point of the titration.

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

(b). The student carries out a trial titration followed by three further titrations, **1**, **2** and **3**.

The results are shown in the table below.

Titration	Trial	1	2	3
Final reading / cm^3	18.70	36.55	18.30	36.60
Initial reading / cm^3	0.20	18.50	0.10	18.30
Titre / cm^3				

[1]

Complete the table to show the titre in each titration.

[1]

i. Why does the student carry out a trial titration?

[1]

ii. Calculate the mean titre of NaOH(aq) that the student should use for analysing the results.

mean titre = ... cm^3 **[1]**

iii. In the titration, the uncertainty in each burette reading is ± 0.05 cm^3.

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

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

(c). Calculate the value of n in $HOOC(CH_2)_n COOH$.
Give your answer to the nearest whole number.

n = ... **[5]**

(d). A 25.0 cm^3 pipette was used to measure out the 25.0 cm^3 of glutaric acid solution for each titration.

Before use, one student washed the pipette out with water instead of the glutaric acid solution.

State the effect of this mistake on the titre.

Explain your answer.

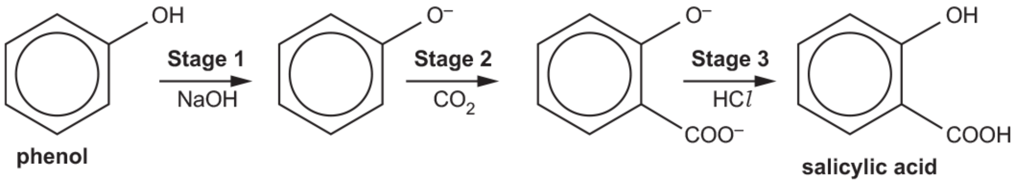
Effect

Explanation

[2]

48. This question is about reactions of phenol.

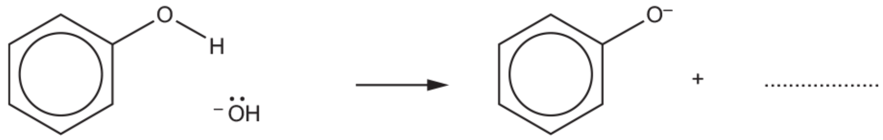
Salicylic acid can be prepared from phenol as shown below.



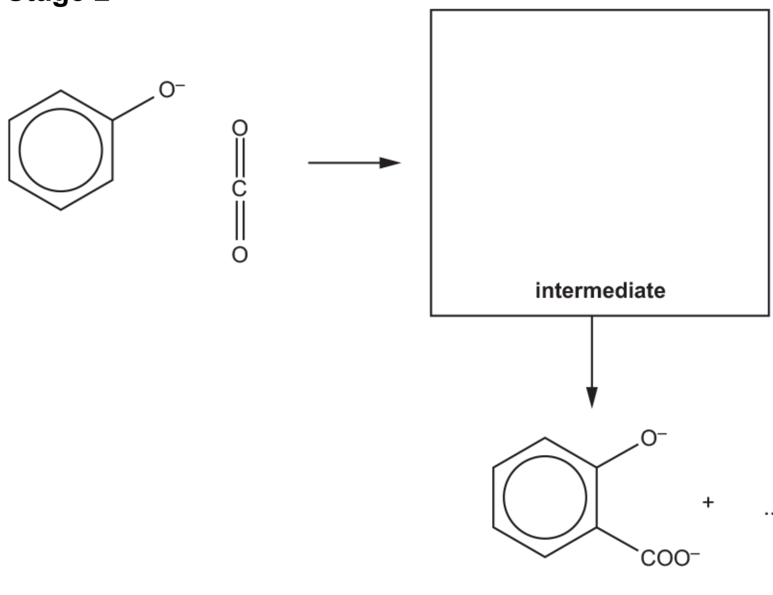
i. Complete the mechanism below for **Stage 1** and **Stage 2**.

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]

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

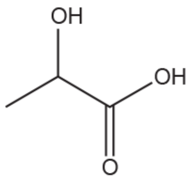
Ca, 81.10%; N, 18.90%.

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]

50(a). This question is about carboxylic acids.

Compound **D** is a *cis* stereoisomer of an unsaturated organic acid with the general formula $C_nH_{2n-1}COOH$.

A student plans to analyse acid **D** by carrying out a titration.

A student first prepares 250.0 cm^3 of a standard solution of 0.150 mol dm^{-3} $Ba(OH)_2$ for the titration.

The student is provided with solid $Ba(OH)_2$ and usual laboratory apparatus and equipment.

Describe how the student would prepare the standard solution, giving full details of quantities, apparatus and method.

[5]

(b). A student prepares a 100.0 cm^3 solution containing 3.215 g of acid **D**.

The student titrates 25.0 cm^3 samples of the solution of **D** with 0.150 mol dm^{-3} $Ba(OH)_2(aq)$ in the burette.

1 mol $Ba(OH)_2$ reacts with 2 mol of **D**.

The mean titre of $Ba(OH)_2(aq)$ is 23.50 cm^3.

Analyse the titration results to determine **two** possible structures for the *cis* stereoisomer of organic acid **D**.

Structures of 2 possible cis stereoisomers of acid D

[7]

51(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]

52(a). Lime is a citrus fruit containing citric acid, $C_6H_8O_7$.

Citric acid is a weak organic acid.

i. What is meant by an **acid**?

[1]

ii. What is meant by an acid that is **weak?**

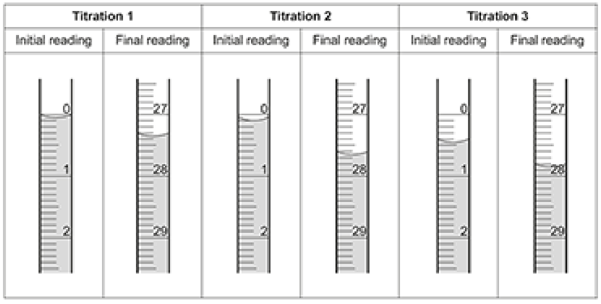
.... **[1]**

(b). A student carries out a titration to determine the mass of citric acid in a lime.
The student follows the method below:

- Squeeze the juice out of two limes.
- Transfer the juice into a $250.0 cm^3$ volumetric flask and make up to the mark with distilled water.
- Pipette $25.0 cm^3$ of the diluted lime juice into a conical flask and add a few drops of phenolphthalein indicator.
- Titrate this solution with $0.800 mol dm^{-3}$ NaOH(aq).

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

The diagram shows the burette readings for the three further titrations.
Each reading is measured to the nearest $0.05 cm^3$.



i. Record the student's burette readings in the table below.

Calculate the mean titre, to the nearest $0.05 cm^3$, that the student should use to analyse the results.

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

mean titre .... cm^3 **[4]**

ii. Citric acid, $C_6H_8O_7$, is neutralised by NaOH as shown in the equation below.

$C_6H_8O_7 + 3NaOH \rightarrow Na_3C_6H_5O_7 + 3H_2O$

Calculate the mass, in g, of citric acid in **one** lime.

Assume that citric acid (M_r = 192.0) is the only acid in lime juice.

mass of citric acid in one lime = ... g **[5]**

(c). The student's teacher thinks that there is an unnecessary safety risk in using a sodium hydroxide concentration of 0.800 mol dm^{-3} for the titration.

Suggest how the student could modify the method using a sodium hydroxide concentration of 0.200 mol dm^{-3} instead of 0.800 mol dm^{-3}.

The student should aim to have the same titre as in the original method.

Justify your answer

[2]

53. This question is about acids and buffer solutions.

Succinic acid, $HOOC(CH_2)_2COOH$, is a weak dibasic acid that is used in tablet form in health supplements.

A student plans to determine the mass of succinic acid in one tablet of a succinic acid health supplement.

The student carries out a titration with potassium hydroxide.

The end point occurs when both acidic protons in succinic acid have been replaced as shown in **Equation 19.1**.

$HOOC(CH_2)_2COOH + 2KOH \rightarrow KOOC(CH_2)_2COOK + 2H_2O$ **Equation 19.1**

The student uses the following method.

Stage 1 The student crushes four tablets of the health supplement and dissolves the powdered tablets in distilled water.

Stage 2 The student makes up the solution from **Stage 1** to 250.0 cm^3 in a volumetric flask.

Stage 3 The student titrates 10.0 cm^3 portions of the solution obtained in **Stage 2** with 0.0600 mol dm^{-3} potassium hydroxide, using phenolphthalein as the indicator.

The student carries out a trial titration, followed by three further titrations.
The results are shown below.

Titration	**Trial**	**1**	**2**	**3**
Final burette reading/cm^3	25.25	23.75	25.35	25.75
Initial burette reading/cm^3	2.50	1.30	2.65	3.20
Titre/cm^3				

i. Complete the table and calculate the mean titre that the student should use for analysing the results.

mean titre = ... cm^3 **[2]**

ii. Use the student's results and **Equation 19.1** to calculate the mass, in mg, of succinic acid in **one** tablet of the health supplement.

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

mass = ... mg **[5]**

54. This question is about the reactions of Group 2 metals and their compounds.

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]

55. Which compound is an alkali?

A CH_3COOH
B CH_3OH
C HNO_3
D NH_3

Your answer ☐ **[1]**

56(a). This question is about reactions involving acids.

Hydrochloric acid and nitric acid are classified as strong acids.

What is meant by a **strong** acid

.... **[1]**

(b). 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]**

(c). A student carries out an investigation to identify an unknown Group 1 metal **M**.

- The student reacts 2.62 g of the Group 1 metal, **M**, with water.
  A solution of the alkali, **M**OH(aq), is formed.
- The student makes this solution of **M**OH(aq) up to 250.0 cm^3 with water.
- The student pipettes 25.0 cm^3 of this **M**OH(aq) solution into a conical flask.
- The student titrates this 25.0 cm^3 volume of **M**OH(aq) with 0.165 mol dm^{-3} H_2SO_4(aq).

The equation is shown below.

$2MOH(aq) + H_2SO_4(aq) \rightarrow M_2SO_4(aq) + 2H_2O(l)$

i. Name the type of flask that the student should use to make up the 250.0 cm^3 solution of **M**OH(aq).

.... flask **[1]**

ii. The student takes burette readings to the nearest 0.05 cm^3.

The student's readings are shown in the table.

The rough titre has been omitted.

Complete the table below.

Final reading / cm^3	20.25	40.85	25.85
Initial reading / cm^3	0.00	20.25	5.50
Titre / cm^3	....	....	....

[1]

iii. Calculate the mean titre of H_2SO_4, to the nearest 0.05 cm^3, that the student should use to analyse the results.

mean titre = ... cm^3 **[1]**

iv. Calculate the amount, in mol, of **M**OH in 25.0 cm^3 of solution and determine the identity of the Group 1 metal **M**.

metal **M** = ... **[4]**

57. 40.0 cm^3 of 0.200 mol dm^{-3} HCl is added to 60.0 cm^3 of 0.100 mol dm^{-3} NaOH.

What is the concentration of the resulting solution?

A 0.0200 mol dm^{-3} HCl and 0.0200 mol dm^{-3} $NaCl$
B 0.0200 mol dm^{-3} HCl and 0.0400 mol dm^{-3} $NaCl$
C 0.0200 mol dm^{-3} HCl and 0.0600 mol dm^{-3} $NaCl$
D 0.0600 mol dm^{-3} HCl and 0.0200 mol dm^{-3} $NaCl$

Your answer ☐ **[1]**

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

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]

(b). A student reacts an excess of magnesium with 25.0 cm^3 of 0.500 mol dm^{-3} hydrochloric acid, HCl.

The student also reacts an excess of magnesium with 25.0 cm^3 of 0.500 mol dm^{-3} ethanoic acid, CH_3COOH.

i. Construct an ionic equation for the reaction of magnesium with an acid.

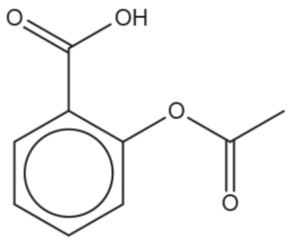
[1]

ii. Explain why these two reactions of magnesium produce the same volume of gas but at different rates.

[3]

59. Aspirin tablets are used for pain relief.

The structure of aspirin is shown below.



Aspirin

A student uses the reaction of aspirin with cold NaOH(aq) to determine the mass of aspirin in **one** tablet.

In this reaction, 1 mol of aspirin reacts with 1 mol of cold NaOH(aq).

The student's method is outlined below.

Step 1	The student reacts **three** aspirin tablets with 100 cm^3 of 0.500 mol dm^{-3} NaOH(aq). The NaOH is in excess. A colourless solution forms.
Step 2	The colourless solution from **Step 1** is made up to 250.0 cm^3 with distilled water.
Step 3	A 25.00 cm^3 sample of the diluted solution from **Step 2** is titrated with 0.200 mol dm^{-3} HC*l* (aq) in the burette.

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

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

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

Titration results
The trial titre has been omitted.

The burette readings have been read to the nearest 0.05 cm^3.

	1	2	3
Final reading / cm^3	23.10	45.40	27.40
Initial reading / cm^3	0.00	23.10	5.00

Analysis of results
From the results, the student can determine the following.

1. The amount, in mol, of excess NaOH(aq) that remains after the reaction of aspirin with NaOH(aq).

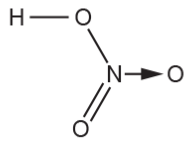
2. The amount, in mol, of NaOH(aq) that reacted with the aspirin.

Use the results to determine the mass, in mg, of aspirin in **one** aspirin tablet.

mass of aspirin in **one** tablet = ... mg **[6]**

60(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]

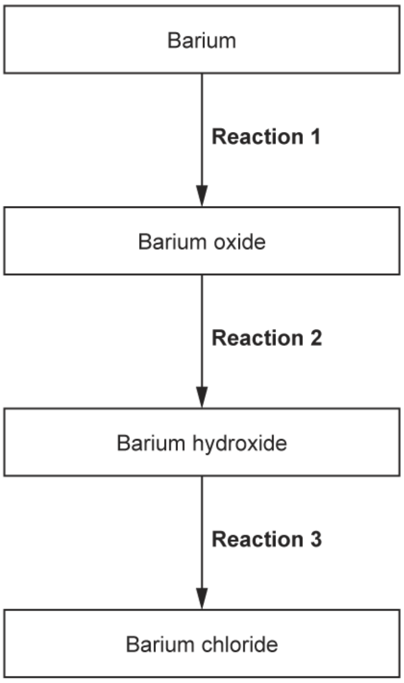
ii. The solution contains nitrate ions, NO_3^-.

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

Use a different symbol for the extra electron.

[2]

61. 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]

62(a). This question is about the reactions of acids.

What is the difference between a **strong** acid and a **weak** acid?

[1]

(b). Ethanoic acid, CH_3COOH, is found in some descalers to soften hard water.

A student carries out a titration with a standard solution of sodium carbonate, Na_2CO_3, to determine the percentage composition by mass of CH_3COOH in a descaler.

The equation is shown below.

$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + CO_2 + H_2O$

i. The method is outlined below:

- Dissolve 6.50 g of the descaler in distilled water.
- Transfer the solution into a 250.0 cm^3 volumetric flask.
- Make up to the mark with distilled water and invert several times.
- Pipette 25.0 cm^3 of this solution into a conical flask and add a few drops of indicator.
- Titrate this solution with 0.200 mol dm^{-3} $Na_2CO_3(aq)$, in the burette.

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

The results are shown in the table below.

The trial titration has been omitted.

Titration	**1**	**2**	**3**
Final reading/ cm^3	48.95	24.15	48.35
Initial reading/ cm^3	24.55	0.00	24.10
Titre / cm^3			

Complete the table by adding the titres.

[1]

ii. Calculate the mean titre, to the nearest 0.05 cm^3, that the student should use for analysing these results.

mean titre = ... cm^3 **[1]**

iii. Calculate the percentage composition by mass of CH_3COOH in the descaler.

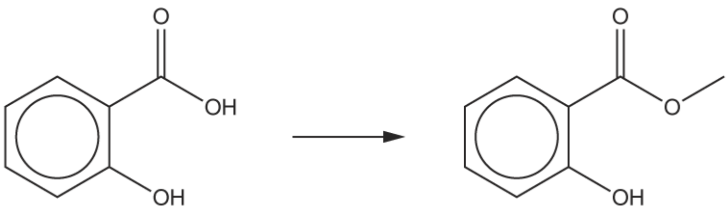
Assume that CH_3COOH is the only acid in the descaler.

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

percentage composition by mass = ... % **[5]**

63. 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.

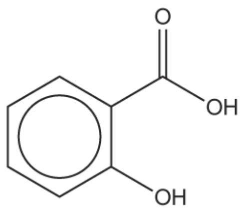
The student follows this method and obtains 5.32 g of pure compound **H**.

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]

64. A student is provided with hydrated copper(II) nitrate, $Cu(NO_3)_2 \cdot 3H_2O$.

The student needs to prepare a standard solution of $Cu(NO_3)_2 \cdot 3H_2O$ with a concentration of 0.200 mol dm^{-3}. The student has access to usual laboratory apparatus and equipment.

Describe how the student would prepare 100.0 cm^3 of this solution, giving quantities, apparatus and method.

[5]

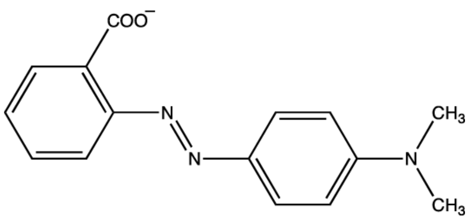
END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2			D	1	
			Total	**1**	
3			A	1	
			Total	**1**	
4		i	HNO_3 is a strong acid **AND** HNO_2 is a weak acid	1	**ALLOW** HNO_3 completely dissociates **AND** HNO_2 partially dissociates **ALLOW** $HNO_3 \rightarrow H^+ + NO_3^-$ **AND** $HNO_2 \rightleftharpoons H^+ + NO_2^-$ **IGNORE** HNO_3 is a stronger acid **ORA** **IGNORE** HNO_3 produces more H^+
		ii	pH = −log 0.0450 = 1.35 (**2 DP** required)	1	
		iii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 2.35, award all **three** calculation marks $K_a = 10^{-3.35}$ **OR** 4.47×10^{-4} (mol dm^{-3}) $[H^+] = \sqrt{(K_a \times [HNO_2])}$ **OR** $\sqrt{(K_a \times [HA])}$ **OR** $\sqrt{(K_a \times 0.0450)}$ **OR** 4.48×10^{-3} (mol dm^{-3}) pH = 2.35 (**2 DP** required)	3	**ALLOW** 2 SF to calculator value: $4.466835922 \times 10^{-4}$, correctly rounded **IGNORE** HNO_3 in working Always **ALLOW** calculator value irrespective of working as number may have been kept in calculator. ***Note:*** *pH = 2.35 is obtained from all three values above* *From no square root, pH = 4.70. Worth K_a mark only.*
			Total	**5**	
5			n(NaOH) used in titration = 0.150 × 18.80 / 1000 = 0.00282 (mol) $n(H^+/COOH)$ in 25.0 cm^3 = 0.00282 (mol) **AND** $n(H^+/COOH)$ in 250 cm^3 = 0.0282 (mol)	5	

			'Molar' mass of **K** = 1.89/0.0282 = 67.0 g mol^{-1} **K** must be diprotic **K** is malic acid / $HOOCCH_2CHOHCOOH$		Determined through realisation that none of the compounds listed have M = 67.0 g mol^{-1}
			Total	**5**	
6			A	1	
			Total	**1**	
7		i	reaction with bases: neutralisation **AND** reaction with metals: redox	1	Enter text here.
		ii	correctly calculates $n(\mathbf{A}) = \frac{1.125}{90} = 0.0125$ (mol) volume of $H_2 = \frac{0.0125}{2} \times 24{,}000 = 150\ cm^3$ **units** required	2	**ALLOW** 0.15 dm^3 **ALLOW ECF** from n(**A**)
		iii	$C_6H_{12}O_6Mg$	1	**DO NOT ALLOW** $(C_3H_6O_3)_2Mg$
		iv	Type of reaction of COOH: e.g. esterification **AND** reagents and conditions e.g. CH_3OH **AND** H_2SO_4 Organic product of COOH reaction Type of reaction of −OH **AND** reagents and conditions Organic product of −OH reaction	4	**ALLOW** esterification with any stated alcohol e.g. product from CH_3OH/H_2SO_4 → $CH_3(CHOH)COOCH_3$ Many possible reactions of secondary alcohol possible, e.g. oxidation with $K_2Cr_2O_7$ / H_2SO_4 + heat → $CH_3(CO)COOH$ elimination with H_2SO_4 / H_3PO_4 + heat → $CH_2 = CHCOOH$ esterification with CH_3COOH / H_2SO_4 **OR** CH_3COCl → $CH_3(CHOOCCH_3)COOH$ bromination with NaBr / H_2SO_4 → $CH_3(CHBr)COOH$ **ALLOW** self-polymerisation as reaction for either group (if another reaction example given) condensation polymerisation with

					H_2SO_4 → $[OCH(CH_3)CO]_n$
			Total	**8**	
8	a	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	
	b	i	*Amount of each element mark* H $\frac{0.025}{1.0}$ O $\frac{0.300}{16.0}$ N $\frac{0.175}{14.0}$ = 0.025 0.01875 0.0125 (1) *Simplest whole number ratio empirical formula* $\frac{0.025}{0.0125} = 2$ $\frac{0.01875}{0.0125} = 1.5$ $\frac{0.0125}{0.0125} = 1$ **AND** $H_4O_3N_2$ (1)	2	**allow** 2 marks for correct answer without working
		ii	acid: HNO_3 **AND** base: NH_3 (1)	1	**allow** atoms within HNO_3 and NH_3 in any order
			Total	**9**	
9	a		volumetric flask **AND** (graduated) pipette	1	**allow** graduated flask **ignore** burette
	b		**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 73.9 or 73.93 (g mol^{-1}) award 3 marks for calculation n(NaOH) = (25.25/1000) × 0.120 = 3.03 × 10^{-3} (mol) (1) n(acid in 250 cm^3 flask) = 3.03 × 10^{-3} × 10	3	**If there is an alternative answer, check to see if there is any ECF credit possible using working below**

			= 3.03×10^{-2} (mol) (1) molar mass of unknown acid = 2.24/3.03 × 10^{-2} = 73.9 (g mol^{-1}) (1)		
	c		Repeat titration until (two) titrations are concordant / agree within 0.1 cm^3 (1) Calculate mean titre from concordant titres (1)	2	**ignore** just 'repeat the titration' (needs qualifying).
			Total	**6**	
10	a	i	Using a pH probe on a data logger **OR** pH meter	1	
		ii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = **0.11(0)** (mol dm^{-3}), award **2 marks** .... $n(NaOH) = \frac{0.125 \times 22.0}{1000} = 2.75 \times 10^{-3}$ (mol) concentration of $CH_3COOH = \frac{2.75 \times 10^{-3} \times 1000}{25.0}$ = 0.11(0) (mol dm^{-3})	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. .... **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW ECF:** *n*(NaOH) × 1000/25.00
	b	i	Brilliant yellow **AND** Vertical section / rapid pH change matches the pH range / end point / colour change (of the indicator)	1	**ALLOW** pH range (of the indicator) matches equivalence point **ALLOW** end point / colour change matches equivalence point **IGNORE** colour change matches end point (*colour change is the same as end point*)
		ii	 Explanation: Acid / H^+ reacts with A^- **AND** equilibrium (position) shifts towards HA (to give a red colour) Alkali / OH^- reacts with HA/H^+ **AND** equilibrium (position) shifts towards A^- (to give a yellow colour)	4	**ALLOW** direction of equilibrium shift if equilibrium shown: $HA \rightleftharpoons H^+ + A^-$ i.e. 'towards HA' is equivalent to 'to left' i.e. 'towards A^-' is equivalent to 'to right'

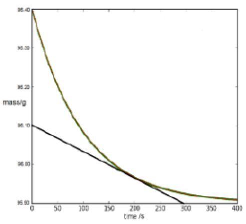
			At end point, equal amounts of HA and A^- **AND** orange colour		**ALLOW** yellow−red colour
			Total	**8**	
11		i	H_3PO_4 ✓	1	**ALLOW** formula if seen as reactant in an equation **IGNORE** name **Examiner's Comments** This question was well answered although it was common to see incorrect formulae such as HPO_4 from weaker candidates.
		ii	Calcium oxide **OR** calcium hydroxide **OR** calcium carbonate ✓	1	**IGNORE** formulae **IGNORE** lime, quicklime and limestone **Examiner's Comments** Nearly all candidates knew the answer to this question, but not all gained the mark here as many gave the formula of the base rather than its name, despite the question stressing the need for the name.
			Total	**2**	
12		i	Hydrogen ✓	1	**ALLOW** H_2 **IGNORE** 'H' **Examiner's Comments** This question was well answered although the erroneous appearance of water as a product of the reaction between an acid and a metal was seen relatively frequently.
		ii	$Ce_2(SO_4)_3$ ✓ (Cerium) loses **three** electrons (to form 3+ ion) ✓	2	**ALLOW** alternative phrases for 'loses' eg 'gives away', 'donates' **IGNORE** '3 electrons transferred' unless a correct direction is given eg **ALLOW** (Ce) transfers 3 electrons to …**OR** (Ce) transfers 3 electrons forming Ce^{3+} **IGNORE** references to sulfate gaining electrons **IGNORE** references to reduction and oxidation **Examiner's Comments**

					This question was slightly more challenging and discriminated well. Some candidates missed the fact that the cerium was in the +3 oxidation state and gave the formula as $CeSO_4$ along with an explanation that involved the loss of 2 electrons. However, a significant number of candidates did not focus upon the instruction in the question to explain 'in terms of the number of electrons transferred' and gave responses based solely upon changes in oxidation number.
		iii	A hydrogen **ion** (of an acid) has been replaced by a metal **ion** ✓	1	For hydrogen ion: **ALLOW** 'H^+' **OR** 'proton' but **DO NOT ALLOW** 'H' **OR** 'hydrogen' without 'ion' For metal ion: **ALLOW** 'cerium ion' **OR** 'Ce^{3+}' **OR** 'Ce^{2+}' **OR** 'Ce ion' But **DO NOT ALLOW** 'Ce' without 'ion' **OR** 'cerium' without 'ion' **IGNORE** 'ammonium ion' **Examiner's Comments** A good number of candidates had no problem with this question but slightly weaker students talked vaguely about the reaction of metals with acids and clearly did not realise that the question was really examining how well they understood the definition of a salt.
			Total	**4**	
13	a	i	Mol of H_2SO_4 = 0.100 × 18.00 / 1000 = 1.80 × 10^{-3} mol ✓	1	**ALLOW** calculator value or rounding to 2 significant figures or more but **IGNORE** 'trailing zeroes' throughout Q4. eg 0.200 is allowed as 0.2 **Examiner's Comments** This opening part to the calculation was relatively straightforward and almost all candidates scored this mark. Even when the mark was not awarded it was often not because of a lack of knowledge of the formula but because the student used the incorrect volume of 29.50 cm^3.
		ii	Mol of NaOH in = 1.80 × 10^{-3} × 2 × 1000 / 25.0 = 0.144 mol dm^{-3} ✓	1	**ALLOW** ECF for (a)(i) × 2 × 1000 / 25 **Examiner's Comments**

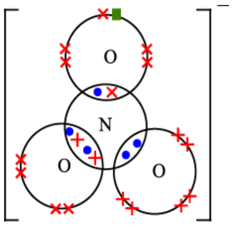
					Candidates who had answered correctly part **(i)** were able to give the right answer here but some muddled the stoichiometric ratio. Another source of error was to use the wrong volume of NaOH, with some opting to use 200 cm^3 as this was the total volume of solution X.
b	i		**Check the answer line.** **If answer = 0.0184 mol award 2 marks** Mol of $NaHCO_3$ in 25.0 cm^3 = [0.100 × 11.50 / 1000] × 2 = 0.00230 mol ✓ Mol of $NaHCO_3$ in 200 cm^3 = 0.00230 × 200 / 25.0 = 0.0184 mol ✓	2	**If there is an alternative answer, check to see if there is any ECF credit possible using working below.** **ALLOW** for an alternative method for M1 Total mol of H_2SO_4 used = [0.100 × 29.50 / 1000] = 0.00295 mol Mol of H_2SO_4 reacting with $NaHCO_3$ = 0.00295 – answer to (a)(i) Expected answer = .00295 – 0.00180 = 0.00115 mol Mol of $NaHCO_3$ in 25.0 cm^3 = 0.00115 × 2 = 0.00230 mol **ALLOW** ECF for **mol** of $NaHCO_3$ × 200 / 25.0 For ECF in M2 titration values of 11.50 or 29.50 must have been used in M1 Second marking point is for scaling up number of mol of $NaHCO_3$ by 200 / 25.0 (Usually seen as '8') **Examiner's Comments** This was probably the most challenging question on the paper and many candidates could not see the route to the answer. Encouragingly many did see the need to find the difference in the two titres and so their calculations did involve 11.50 cm^3. The second mark for scaling up the amount was not often awarded.
	ii		Mass of $NaHCO_3$ = 0.0184 × 84.0 = 1.55 g ✓ **(must be three significant figures)**	1	**ALLOW** ECF for **(b)(i)** × 84.0 correctly calculated and rounded to three significant figures. **Examiner's Comments**

					In essence this was a very easy question that simply required candidates to multiply their answer to (i) by 84.0 and give the answer to 3 significant figures.
			Total	**5**	
14	a		Base: A substance which readily accepts H^+ ions (from an acid) ✓ Alkali: releases OH^- ions into (aqueous) solution ✓	2	**ALLOW** proton acceptor **ALLOW** Is soluble and releases OH^- ions (into aqueous solution) **Examiner's Comments** Of the two parts, the definition of base was more often given correctly. A few weaker candidates described a base in terms of the reaction with acids to give salts but most gave the correct answer. The description of an alkali was less well answered with some commenting on the presence of OH^- ions and others on the solubility but few doing both.
	b		Nitric acid **OR** HNO_3 ✓ $CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$ ✓	2	**ALLOW** reagent mark if no response is seen but HNO_3 is seen in the equation **IGNORE** calcium carbonate on reagent line **ALLOW** multiples **IGNORE** state symbols **DO NOT ALLOW** H_2CO_3 for $H_2O + CO_2$ **Examiner's Comments** Most students identified the reagent as nitric acid but the equation proved more challenging. Most common errors were to give the formula as H_2NO_3 or calcium nitrate as $CaNO_3$.
			Total	**4**	
15	a	i	carbon dioxide lost/evolved/given off/or produced as a gas ✓	1	**DO NOT ALLOW** water or steam or CO_2 evaporates **Examiner's Comments** Candidates who failed to state that the gas being lost was CO_2 could not access the mark for this question. Vague answers relating to water being produced, products

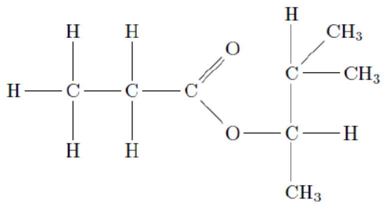
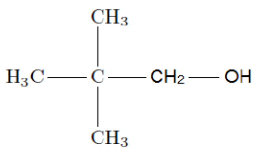
					being gases, products being lost or a gas evolved were often given by Candidates.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 1.85 OR 1.845 g award 3 marks** .... *n*(HNO_3) $= 1.25 \times \frac{20.0}{1000} = 0.0250$ mol ✓ *n*($SrCO_3$) $= \frac{0.0250}{2} = 0.0125$ mol ✓ *m*($SrCO_3$) = 0.0125 × 147.6 = 1.845 g **OR** 1.85 g ✓	3	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW ECF** from incorrect *n*(HNO_3) molar mass of $SrCO_3$ = 147.6 (g mol^{-1}) **ALLOW ECF** from incorrect *n*($SrCO_3$) **Examiner's Comments** The vast majority of candidates were able to complete this calculation arriving at the correct answer to score all three available marks. The most common error was in calculating the amount, in moles, of the $SrCO_3$ from the stoichiometry given in the equation. This resulted in an answer which was twice that expected however two marks could still be obtained by applying error carried forward. Answer = 1.845 g or 1.85 g
	b	i	rate of reaction decreases **AND** concentration decreases / reactants are used up ✓	1	**ALLOW** reaction slows down **ALLOW** concentration of reactants decreases.
		i	less frequent collisions ✓	1	**ALLOW** fewer collisions per unit time **OR** collisions less often **OR** decreased rate of collision **IGNORE** less successful collisions / less collisions less chance of collisions **Examiner's Comments** Very few candidates were able to explain the change in the rate of the reaction during the first 200 seconds of the experiment. This relatively straightforward question

					required a statement that the rate decreases as the concentration of the reactants decreases due to there being less frequent collisions. Although a large number of candidates were able to state that the rate decreases few were able to explain why. This was possibly due to candidates having to apply their understanding in an unfamiliar context rather than from a lack of knowledge
		ii	Attempted tangent on graph drawn to line at approximately t = 200 s ✓	1	
		ii	Gradient (y/x) e.g. $\frac{0.20}{290}$ = 6.9×10^{-4} ✓ 	1	**ALLOW** 1 SF up to calculator value, in range 5×10^{-4} to 8×10^{-4} **IGNORE** units **IGNORE** sign **Examiner's Comments** This was the first time AS level candidates have been required to calculate a rate of reaction from a graph and many found this quite testing. Although many knew that a tangent was required only the most able candidates were able to arrive at a value for the gradient that was within the expected range. Candidates sometimes took as their values the point at which their tangent cut the axes rather than calculating the change in mass or change in time. Acceptable range 5×10^{-4} to 8×10^{-4}
	c		Flask **OR** beaker **AND** balance **AND** stopwatch **OR** stop clock **OR** other timing device ✓	1	**DO NOT ALLOW** round-bottomed flask. **IGNORE** weighing scales
			Records **mass** at time intervals ✓	1	**ALLOW** 'weigh at time intervals'
			Time interval quoted between 10-50s ✓	1	**Examiner's Comments** This was the second question that required candidates to describe an experiment that they could have carried out as part of their course. Even if this experiment had not

					been completed in class, candidates should be able to recognise that mass needs to be measured over a period of time. As the reaction was between an acid and a carbonate a suitable named reaction vessel such as a beaker or flask was required. A balance was needed for mass measurement and a timing device to monitor time. A simple statement that mass should be recorded at a given time interval scored two marks with one mark being allocated to suitable apparatus. At this level it is expected that candidates will be familiar with the correct names for the apparatus required to carry out an investigation.
			Total	**11**	
16		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).
			Total	**2**	
17			A	1	**<u>Examiner's Comments</u>** Candidates were clearly unsure on how to classify a neutralisation reaction, with D being a common incorrect answer.
			Total	**1**	
18		i	NiO + $2HNO_3 \rightarrow Ni(NO_3)_2 + H_2O$ ✓	1	**ALLOW** multiples **IGNORE** state symbols (even if wrong) **<u>Examiner's Comments</u>**

					This part was surprisingly poorly answered. Common errors included incorrect formulae for nickel(II) oxide and HNO_3, and H_2 shown as a product instead of H_2O.
		ii	 **Global rules** • N and O electrons must be shown differently, e.g. • for N and × for O • 'Extra' electron shown with different symbol **MARKING** ***Bonding around central N atom*** ✓ ○ 5 electrons for N shown as • **OR** × ○ 3 electrons for O, different from N as • **OR** × • N=O bond with 2 N electrons **AND** 2 O electrons • N→O bond with 2 N electrons • N–O bond with 1 N electron **AND** 1 O electron ***Non-bonded (nb) electrons around 3 O atoms*** ✓ • N=O oxygen has 4 nb 'O' electrons • N→O oxygen has 6 nb 'O' electrons • N–O⁻ oxygen has 5 nb 'O' electrons **AND** 1 'extra' electron with different symbol	2	**NOT REQUIRED** • Charge ('−') • Brackets • Circles **IGNORE** inner shells **ALLOW** rotated diagram **ALLOW** diagram with missing N or O symbols. *Shown as diagram on QP anyway* In **N=O bond**, **ALLOW** sequence **× × • •** In **N–O bond**, **ALLOW** 'extra' electron with different symbol for O electron **ALLOW** non-bonding electrons unpaired If 'extra' electron has been used **in N–O$^-$ bond**, N–O$^-$ oxygen **MUST** have 6 nb 'O' electrons **ALLOW** 'extra' electron as • **OR** × if it has been **labelled** 'extra electron' or similar **<u>Examiner's Comments</u>** Most candidates attempted this novel *'dot-and-cross'* diagram. Many candidates correctly showed the bonding electrons around the central nitrogen atom. The remaining electrons around the oxygen atoms proved to be more difficult, with many omitting to show the 'extra electron'.

			Total	3	
19	a		<u>Reducing agent</u> $NaBH_4$ / sodium tetrahydridoborate(III) / sodium borohydride✓ <u>Equation</u> $CH_3(CH_2)3CHO + 2[H] \rightarrow CH_3(CH_2)3CH_2OH$ ✓	1	**ALLOW** $LiAlH_4$/lithium tetrahydridoaluminate(III)/lithium aluminium hydride **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above **ALLOW** $C_4H_9CHO + 2[H] \rightarrow C_5H_{11}OH$ **ALLOW** molecular formulae: $C_5H_{10}O + 2[H] \rightarrow C_5H_{12}O$ **DO NOT ALLOW** –COH for aldehyde **Examiner's Comments** Very well answered. The most common error was an incorrect formula for the aldehyde.
	b		**M1** Compound **F** structure is a secondary alcohol with the formula $C_5H_{11}OH$ ✓ **M2** Compound **F** = $CH_3CH(OH)CH(CH_3)CH_3$ ✓ **M3** Compound **G** = $CH_3COCH(CH_3)CH_3$ ✓	7	**ANNOTATE WITH TICKS AND CROSSES ETC** **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **IGNORE** names if structures are given **ALLOW** 3-methylbutan-2-ol if structure not given **ALLOW ECF** from an incorrect secondary alcohol for **M3** e.g. pentan-2-ol → pentan-2-one e.g. pentan-3-ol → pentan-3-one **ALLOW** (3-)methylbutanone if structure not given **IGNORE** any discussion of the reactions of compound **G** with 2,4-dinitrophenylhydrazine and/or Tollens' reagent. **ALLOW 3 SF** up to calculator value correctly rounded

			M4 n(NaOH) = (0.125 x 22.8/1000) = 0.00285 (mol) ✓ **M5** M(compound H) = (0.211/0.00285 =) 74(.0) (g mol^{-1}) ✓ **M6** Compound **H** = / CH_3CH_2COOH ✓ **M7** Compound **I** =  ✓		**IF** M(compound H) = 74 award 2 marks (M4 + M5) **ALLOW ECF** from incorrect calculation of amount of NaOH **ALLOW** propanoic acid if structure not given **ALLOW ECF** from incorrect compound **F** (alcohol) and/or incorrect compound **H** (carboxylic acid) to form compound **I** (ester). Compounds **F**, **G**, **H** and **I** must be placed in the correct box or correctly labelled for **M2**. **M3**, **M6** and **M7** **Examiner's Comments** A high scoring question with many candidates gaining full marks. Although most realised that Compound F was a secondary alcohol, fewer candidates combined this knowledge with the information provided by carbon-13 NMR to deduce the correct structure of the secondary alcohol.
	c		The structural isomer is:  ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** 2,2-dimethylpropan-1-ol **Examiner's Comments** A good discriminator but many correct structures were seen.
			Total	**10**	
20	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

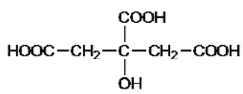
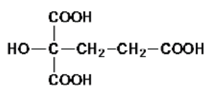
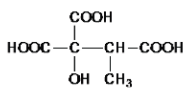
					$1s^2 2s^2 2p^6 3s^2 3p^6$ **Examiner's Comments** The responses seen were very mixed. Able candidates scored the two marks easily but many errors were seen, particularly by removal of 3d electrons rather than 4s electrons from copper atoms to give the electron configurations of the ions (especially for Cu^+ in CuI).
	b		**IGNORE** any charges shown within formulae (treat as rough working) $CuCO_3 + 2HCOOH \rightarrow Cu(HCOO)_2 + H_2O + CO_2$ **OR** $CuO + 2HCOOH \rightarrow Cu(HCOO)_2 + H_2O$ **OR** $Cu(OH)_2 + 2HCOOH \rightarrow Cu(HCOO)_2 +$ **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		$2Cu^{2+} + 4I^- \rightarrow 2CuI$**(s)** $+ I_2$ ✓ State symbol for CuI(s) **ONLY** required	1	**ALLOW** multiples, e.g. $Cu^{2+} + 2I^- \rightarrow CuI$**(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 ✓	2	**IGNORE** 'brown' in composite colour with blue or black, i.e.

			MARK INDEPENDENTLY		**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) ✓ $\boldsymbol{x} = \frac{72(.0)}{18(.0)} = 4$ **WHOLE NUMBER** needed **AND** evidence of working ✓	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) ✓ $\boldsymbol{x} = \frac{0.0395}{9.87 \times 10^{-3}} = 4$ ✓ **ALLOW** $Cu(HCOO)_2 \bullet 4H_2O$ .... **COMMON ERRORS for 4 marks** $\boldsymbol{x}$ = 117 (calc 116.78) *Use of 9.87 × 10^{-4} (no scaling × 10) → M =* 2255.319 $\boldsymbol{x}$ = 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**	
2 1		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*** $n(NaOH) = 1.5(0) \times \frac{50.0}{1000} = 0.075(0)$(mol) **OR** $n(H_2SO_4) = 1.5(0) \times \frac{25.0}{1000} = 0.0375(0)$ (mol)	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

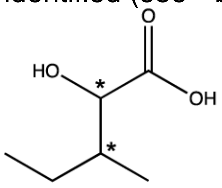
			OR $n(H_2O)$ formed =0.075(0) (mol) ✓ $\Delta_{neut}H = -\frac{4.23225}{0.075} = -56.43$ **OR** −56.4 (kJ mol^{-1}) ✓ − sign **required**		**ALLOW ECF** from $\frac{\text{calculated energy change}}{\text{calculated moles } H_2O}$ **ALLOW** 3 significant figures up to calculator value correctly rounded
			Total	**6**	
22	a		$n(H_2O)$ = 27.55/18.0 = 1.5306 (mol) ✓ $n((NH_4)_2Fe(SO_4)_2)$ = 72.45/284.0 = 0.2551 (mol) ✓ whole number ratio of $(NH_4)_2Fe(SO_4)2$: H_2O = 0.2551 : 1.5306 = 1 : 6 **OR** x = 6 ✓	3	**If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW** calculator value or rounding to two significant figures or more but **IGNORE** 'trailing zeroes' if wrong *M* produces such numbers throughout. **ALLOW ECF** If no working, **ALLOW** 1 mark for *x* = 6.
	b	i	To neutralise acidic soil ✓	1	
		ii	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Describes practical details of tests and observations that allows all four ions to be identified **AND** Attempts associated equations, with most correct. *There is a well-developed line of reasoning and the method is clear and logically structured. The information presented is relevant and substantiated by observations from the tests described and practical details.* **Level 2 (3–4 marks)** Describes most practical details of tests	6	**Indicative scientific points may include** **Practical details:** • Sample stirred with water and mixture filtered. • SO_4^{2-}, Fe^{2+}, NH_4^+ tests on filtrate. • CO_3^{2-} test on residue or garden product **Tests and associated equations:** CO_3^{2-} test: *Test:* Add nitric acid. *Observation:*effervescence. *Equation:* $CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$ ***ALLOW*** $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ ***OR*** overall equation of $CaCO_3$ and an acid.

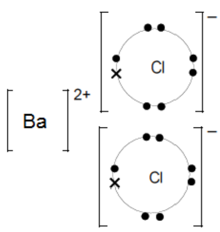
			including the observations that allows most ions to be identified **AND** Attempts associated equations, with some correct. *There is a line of reasoning presented and the method has some structure. The information presented is in the most-part relevant and supported by some evidence of observations from the tests described but practical details may be absent.* **Level 1 (1–2 marks)** Describes some of the practical details of tests and observations would only allow some ions to be identified. **OR** Attempts associated equations, with some correct. *The information is basic and the method lacks structure. The information is supported by limited evidence of the observations, the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		SO_4^{2-} test: Add $BaCl_2(aq)/Ba(NO_3)_2(aq)/Ba^{2+}(aq)$. Observation: white precipitate. Equation: $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ Fe^{2+} test: Test: Add NaOH(aq) Observation: green precipitate Equation: $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ NH_4^+ test: *Test:* Add NaOH(aq) and warm *Observation:* gas turns red litmus indicator blue *Equation:* $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$
			Total	**10**	
23		i	Complete dissociation would give $[H^+]$ = 0.2 (mol dm^{-3}) ✓ pH from complete dissociation = −log 0.2 = 0.7 **OR** actual $[H^+] = 10^{-0.96} = 0.11$ (mol dm^{-3})✓ **Stage 1** is complete dissociation **AND** **Stage 2** is partial dissociation ✓	3	**IGNORE Stage** 1 is a strong acid **AND Stage 2** is a weak acid.
		ii	Observation: fizzing ✓ H^+ reacts with carbonate **AND** (Stage 2) equilibrium shifts to the right ✓	2	**ALLOW** effervescence/'bubbling'
			Total	**5**	

2 4			*Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive analysis of the information available with through explanations linked to the evidence. Acid **C** identified as a tricarboxylic acid with a tertiary −OH group and the correct molecular formula of $C_6H_8O_7$. *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)** Analysis of the information available but explanations may be incomplete or there may be mistakes in calculations, although the method may be sound. *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)** A simple analysis of the information available and limited explanations which may or may not be explicitly linked to the evidence. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** − No response worthy of credit.	6	**Indicative scientific points may include** **Identification of functional groups** • Tribasic acid → three −COOH groups *From 1 mol **C** requires 3 mol NaOH* • Tertiary alcohol *From no colour change with hot acidified dichromate(VI)* **Determination of molecular formula of C** • $M(\mathbf{C}) = \frac{2.323}{1.21 \times 10^{-2}} = 192$ (g mol^{-1}) *From 1.21×10^{-2} mol **C** has a mass of 2.323 g.* • 192 − 3 × 45 (3 × COOH) − 16 (O) = 41 41 → C_3H_5 *(or evidence of working)* • Molecular formula = $C_6H_8O_7$ **Structure of citric acid** • 4 peaks in ^{13}C NMR → 4 types of carbon • Correct structure of **C** matching evidence.  **NOTE**: Structure below match all evidence except for ^{13}C NMR. See Level 3 criteria.  
			Total	**6**	
2 5			**B**	1	**ALLOW** 20 in the box
			Total	**1**	

26			**C**	1	**ALLOW** 4.1 in the box
			Total	**1**	
27			D	**1**	**Examiner's Comments** This question differentiated well. It appeared as if many candidates did not multiply the maximum error by 2 or used the final reading as opposed to a calculated titre.
			Total	**1**	
28		i	***Burette readings*** Final (reading) /cm^3 23.15 45.95 32.45 Initial (reading) /cm^3 0.60 23.15 10.00 ✓ • Correct titration results recorded with initial and final readings, clearly labeled **AND** all readings recorded to two decimal places with last figure either 0 or 5 ***Titres*** Titre / cm^3 22.55 22.80 22.45 ✓ • Correct subtractions to obtain final titres to 2 DP ***Units*** • Units of cm^3 for initial, final and titres ✓ ***Mean titre***	**4**	Table **not** required **ALLOW** initial reading before final reading **ALLOW ECF** **ALLOW** units with each value **ALLOW** brackets for units, i.e. (cm^3) **ALLOW ECF** from incorrect concordant titres

			• mean titre $= \frac{22.55 + 22.45}{2} = 22.50$ **OR** $22.5\ cm^3$ ✓ *i.e. using concordant (consistent) titres*		**Examiner's Comment:** This question should have been four straightforward marks, but it was actually found very challenging by candidates. Most read the scales correctly but then did not present their findings clearly, often scattering unlabelled numbers around, omitting units with absence of any heading linking them to the burettes. 0.60 was very often shown as 0.6 and 22.80 as 22.8. Candidates were expected to take the mean of their closest titres but a significant number took an average of all three titres instead. The mark scheme allowed for a mean titre obtained from incorrect titres. Candidates need to appreciate the importance of communicating their results in a clear and comprehensive way with headings and units, and showing numerical values to the accuracy of the apparatus used.
		ii	**ALLOW 3SF** or more throughout **IGNORE** trailing zeroes, e.g. **ALLOW** 0.084 for 0.0840 .... $n(NaOH) = 0.0840 \times \frac{22.50}{1000} = 1.89 \times 10^{-3}$ (mol) ✓ n(**A**) in 250 cm^3 = 10 × 1.89 × 10^{-3} = 1.89 × 10^{-2} (mol) ✓ $M(\mathbf{A}) = \frac{2.495}{1.89 \times 10^{-2}} = 132$ ($g\ mol^{-1}$) ✓ M(alkyl group) (= 132 – 75) = 57 ✓ R = C_4H_9 ✓ **ALLOW** alkyl group in drawn structure with straight chain or branch (es) in wrong position,	6	**ALLOW ECF** from incorrect mean titre in **4a(i)** e.g. From 22.60 cm^3 (mean of all 3 titres in **(i)**, n(NaOH) = 1.8984 × 10^{-3} (mol) **ALLOW ECF** from incorrect n(NaOH) **ALLOW ECF** from incorrect n(**A**) **ALLOW ECF** from incorrect M(**A**) – 75 **ALLOW ECF** for alkyl group closest to calculated M(alkyl group), e.g. for M = 45, **ALLOW** C_3H_7 (43)

			e.g. for R = C_4H_9, $CH_3CH_2CH_2CH_2$ **OR** $(CH_3)_3C$ Structure with chiral carbon atoms identified (see * below)  ✓		**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous **IGNORE** poor connectivity to OH groups *Given in question* .... **Common error for 4 marks max** *25.00 instead of 22.50 and scaling by × 10* $2.10 \times 10^{-3} \rightarrow 2.10 \times 10^{-2}$ ✓ → 118.81 ✓ → 43.81 ✓ → C_3H_7 ✓ *25.00 instead of 22.50 and scaling by* $\times \frac{250}{22.50}$ $2.10 \times 10^{-3} \rightarrow 2.33 \times 10^{-2}$ ✓ → 106.93 ✓ → 31.93 ✓ → C_2H_5 ✓ No structure with 2 chiral centres possible. **Examiner's Comment:** Most candidates made some headway with this problem. Candidates were expected to process their mean titre from 4(a)(i) in a conventional titration calculation to arrive at a molar mass of 132 g mol^{-1}. From there, candidates could determine a C_4H_9 alkyl group and draw the structure of compound A with two chiral carbon atoms. Most candidates scored some marks but processing beyond the molar mass proved to be difficult for weaker candidates. Some candidates showed a structure with a linear C_4H_9 group which contains one chiral carbon atom. A common error was use of 25.0 cm^3, instead of the titre, as the volume of NaOH, obtaining an initial value of 2.10×10^{-3} mol. The mark scheme allowed processing of this value to be credited using error carried forwards. Some candidates omitted to scale their initial value by a factor of ×10, obtaining a molar mass of over 1000 g mol^{-1}, e.g. 1320 instead of 132. A large range of marks was seen and the question discriminated extremely well.
			Total	**10**	

29			(Acid) releases H^+ ions/ H^+ donor **AND** (weak acid) partially dissociates/ionises ✓	**1**	**ALLOW** H^+ **OR** proton **IGNORE** vague responses that do not imply a number, e.g. • poor proton donor **IGNORE** 'doesn't easily dissociate' **IGNORE** 'a strong acid completely dissociates' *Question is about a weak acid* **Examiner's Comments** Most candidates were aware that an acid is a proton donor but many candidates gave imprecise responses for the concept of a weak acid. Good candidates used the expected term 'partial dissociation', but weaker candidates often focused on a lower concentration of hydrogen ions, pH range or indicator colour.
			Total	**1**	
30			$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$ ✓	1	**ALLOW multiples** **IGNORE** state symbols (even if wrong) **Examiner's Comments** Most candidates were able choose hydrochloric acid as the reagent that would form $BaCl_2$ as a product in a neutralisation reaction but a significant number were unable to balance this straightforward equation.
			Total	**1**	
31		i	 Barium ion with no (or eight) electrons **AND** two chloride ions with correct *dot-and-cross* octet (1)	2	**For the first mark**, if eight electrons are shown in the cation then the 'extra' electron in the anion must match the symbol chosen for electrons in the cation **ignore** inner shell electrons Circles **not** essential **allow** One mark if both electron arrangement and charges are correct but only one *Cl* is drawn allow $2[Cl]^-$ (Bracket not required)

			Correct charges (1)		
		ii	Barium hydroxide **OR** barium oxide **OR** barium carbonate	1	**allow** $Ba(OH)_2$ **OR** BaO **OR** $BaCO_3$
			Total	**3**	
32	a		Not correct about the solid remaining in the weighing bottle (weighed by difference) **AND** Correct about the solution in the beaker (1) Rinse out the beaker with distilled water and transfer to the volumetric flask **before** making up to 250 cm^3 (1)	2	
	b	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	
	c	i	*n*(HC*l*) = (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) 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)	4	**Note**: molar mass is between K_2CO_3 (138.2) and $SrCO_3$ (147.6); only possible match for a Group 1 carbonate is K_2CO_3.
			Total	**10**	

<table>
<tr><td>3
3</td><td>a</td><td></td><td>A solution of known concentration ✓</td><td>1</td><td>ALLOW description of concentration

<u>Examiner's Comments</u>

Many candidates gave a good description of standard conditions or stated 1 mol dm^{-3}, but that did not answer the question so no marks could be credited.</td></tr>
<tr><td></td><td>b</td><td></td><td>Releases OH^- (ions in aqueous solution) ✓</td><td>1</td><td>ALLOW containing OH^- ions
IGNORE mention of pH

<u>Examiner's Comments</u>

Many candidates stated a Brønsted–Lowry definition or gave pH values. Of the candidates that did mention OH^- ions, most did not state 'releases' OH^- ions in solution, although they were credited with the mark.</td></tr>
<tr><td></td><td>c</td><td>i</td><td><table><tr><td>Final reading/ cm^3</td><td>27.30</td><td>27.00</td><td>27.75</td></tr><tr><td>Initial reading/ cm^3</td><td>0.45</td><td>0.60</td><td>1.25</td></tr><tr><td>Titre/cm^3</td><td>26.85</td><td>26.40</td><td>26.50</td></tr></table>
Initial and final readings
All burette readings (×6) correct ✓

Titres recorded to two decimal places with the last figure either 0 or 5
Correct subtractions to obtain final titre values ✓

Mean titre calculated from concordant results
Correct mean titre = 26.45 (cm^3) ✓

Mean titre recorded to accuracy of burette
Final answer recorded to two decimal places with the last figure either 0 or 5 ✓</td><td>4</td><td>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC

ALLOW missing zeroes for burette readings
i.e. 0.6 for 0.60
27 OR 27.0 for 27.00

ALLOW ECF from incorrect burette readings

IF MEAN IS CALCULATED FROM ECF, IT MUST BE FROM CLOSEST TITRES

ALLOW ecf from incorrect mean
DO NOT ALLOW 26.5 cm^3
Question asks for nearest 0.05 cm^3

<u>Examiner's Comments</u>

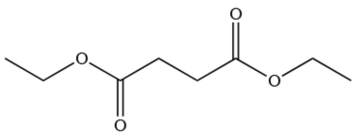
Most candidates were able to accurately record the burette readings and made the correct subtractions. Despite the examination question requesting the mean titre to be recorded to the accuracy of the burette, many candidates did not do this. A common error was taking a mean of all three readings instead of only the concordant results; this led the candidates</td></tr>
</table>

					to give an answer of 26.58 which lost them 2 marks.
		ii	$\frac{2 \times 0.05}{26.85} \times 100 = 0.37(2)$ (%) ✓	1	**ALLOW** 0.4 up to full calculation display of 0.372439478 **ALLOW ECF FOR CORRECT CALCULATION FROM 1 (c) (i) OR USE OF ANY TITRE** **<u>Examiner's Comments</u>** A good attempt by many candidates but some did not know how to calculate this or did not multiply by 2.
		iii	Use a (250 cm^3) **volumetric** flask (instead of a beaker)✓	1	**IGNORE** graduated flask **<u>Examiner's Comments</u>** Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.
d		i	**FIRST CHECK ANSWER ON ANSWER LINE** If answer = 118 (g mol^{-1}) award 4 marks If answer = 108 (g mol^{-1}) award 3 marks ——— *n*(NaOH) $= 0.112 \times \frac{25.0}{1000} = 0.00280$ (mol) ✓ *n*(**A**) in 25.0 cm^3 $= \frac{0.00280}{2} = 0.00140$ (mol) ✓ **n**(**A**) in 250 cm^3 $= 0.00140 \times \frac{250.0}{27.30} = 0.0128$ (mol) ✓ Molar mass, *M*(**A**) to nearest whole number. $= \frac{1.513}{0.0128} = 118$ (g mol^{-1}) ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** Throughout: **IGNORE** trailing zeroes in intermediate working, e.g. For *n*(NaOH) **ALLOW** 0.0028 for 0.00280 **ALLOW ECF** from incorrect *n*(NaOH) **ALLOW ECF** from incorrect *n*(A) **OR** *n*(NaOH) **ALLOW** 3 sig fig up to full calculator display correctly rounded (0.012820512) **ALLOW ECF** from incorrect *n*(NaOH) ——— **Possible ECFs for 3 marks** 1.513 ÷ (0.00140 × 250/25) = 108 1.513 ÷ 0.00140 = **1081** No ÷2 for n(**A**) • Molar mass **A** = 59 (g mol^{-1})

					Using mean titre of 26.45 cm^3 from **1c(i)** • Molar mass **A** = 114 (g mol^{-1}) Using 27.3 × 0.112 in M1 and then 25.0 in M3 • Molar mass **A** = 99 (g mol^{-1}) **Examiner's Comments** Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.
		ii	Structure of dicarboxylic acid $HOOCCH_2CH_2COOH$ **OR** $HOOCCH(CH_3)COOH$ ✓ **STRUCTURE MUST MATCH M_r** from answer to 1 d) i) (within 10 AMU)	1	**ALLOW** correct structural **OR** skeletal **OR** displayed formulae **OR** a combination **ALLOW** incorrect connectivity e.g -HO **ALLOW ECF** from incorrect molar mass in **(d)(i)** but only if 2 × COOH possible and M_r is a close match to **(d) (i) within 10 AMU** **Examiner's Comments** Most candidates that obtained a sensible value for the previous question managed to draw a creditable structure. Allowing error carried forward meant that feasibly derived structures could be credited a mark.
			Total	**13**	
34			**D**	**1 (AO 2.4)**	**Examiner's Comments** The majority of candidates were able to calculate the correct answer.
			Total	**1**	
35		i	Titres correct and **ALL** recorded to **2 decimal places** Titre: 24.00 23.40 23.75 23.85 ✓ mean titre = 23.80 (cm^3) ✓	2	**ALLOW** 23.8 cm^3

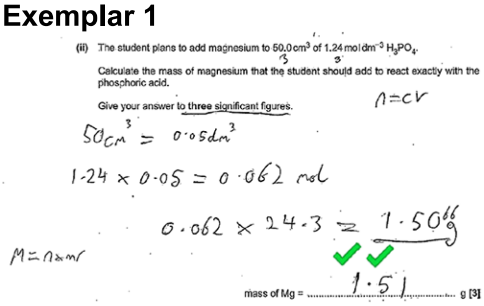
					<u>Examiner's Comments</u> It is clear candidates are not as experienced at filling in titration tables as might be expected. Every value in a titration table should be recorded to a second decimal place to an accuracy of ± 0.05 cm^3. The average titre should be calculated by averaging concordant titres, i.e. those within 0.10 cm^3 of each other.
		ii	Percentage uncertainty $= \frac{0.05 \times 2}{23.40} \times 100 = 0.43$ (%) ✓	1	**ALLOW ECF** from incorrect subtraction in **(i)** or incorrect mean **ALLOW** 0.42% from titre values 2, 3 or 4 or mean titre or trial titre. **2 DP required** **<u>Examiner's Comments</u>** Candidates are unfamiliar with determination of percentage uncertainty. Marks were credited for any percentage uncertainty calculation correctly determined from any titre value, as many opted to choose the trial value as titre 1 or used an average titre.
		iii	Add starch (near the end point) ✓ Blue to colourless ✓	2	**ALLOW** blue/black **OR** black **OR** purple for colour of mixture **ALLOW** blue colour disappears (to colourless) **IGNORE** 'clear' **IGNORE** 'colorimetry' **<u>Examiner's Comments</u>** Only the higher ability candidates realised starch needed to be added close to the end-point and this made the resulting colour change (blue-black to colourless) easier to see. The common error was to assume this was an acid-base titration and indicators such as methyl orange or phenolphthalein should be added.

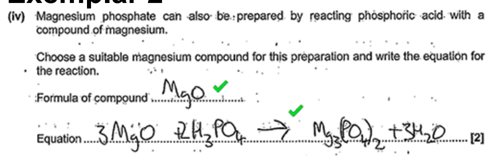
			Answer	Marks	Guidance
		iv	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF B = $RbIO_3$ AND relative formula mass = 260.5 award 5 marks** **IF relative formula mass = 260.5 award 4 marks** -- ***n*($S_2O_3^{2-}$) in titration** $= \frac{0.150 \times 23.80}{1000} = 3.57 \times 10^{-3}$ (mol) ✓ ***n*(IO_3^{-}) in titration** $= \frac{3.57 \times 10^{-3}}{6} = 5.95 \times 10^{-4}$ (mol) ✓ ***n*(IO_3^{-}) in original 250 cm^3** $= 10 \times 5.95 \times 10^{-4} = 5.95 \times 10^{-3}$ (mol) ✓ **Relative formula mass of B** $= \frac{1.55}{5.95 \times 10^{-3}} = 260.5$ (g mol^{-1}) ✓ **Formula of B (must be derived from relative formula mass)** Iodate of Group 1 metal that most closely matches calculated molar mass of **B** Formula from 260.5 = $RbIO_3$ ✓	5	**ALLOW ECF** from incorrect mean titre in **(a)(i)** **ECF** from *n*($S_2O_3^{2-}$) in titration **ALLOW** a two-step calculation *n*(I_2) = *n*($S_2O_3^{2-}$) ÷2 and *n*(IO_3^-) = *n*(I_2) ÷3 **ECF** from *n*(IO_3^-) in titration **ECF** from *n*(IO_3^-) in original 250 cm^3 **IF** scaling × 10 is omitted, **ALLOW ECF** from *n*(IO_3^-) in titration **ALLOW ECF** from incorrect RFM of **B** provided metal is from Group 1 **ALLOW** $RbIO_3$– **DO NOT ALLOW** $RbIO_3$ without relative formula mass value. **DO NOT ALLOW** 260.4 (without working) and $RbIO_3$ **IF B** = $RbIO_3$ AND relative formula mass = 261 award 5 marks **<u>Examiner's Comments</u>** This unstructured calculation was done well by the higher ability candidates. Lower ability candidates struggled to show what they were attempting to calculate and in particular did not appreciate the 1 : 6 ratio of $S_2O_3^{2-}$(aq) to IO_3^-(aq). Candidates might be advised to start *n*(formula) = … at the start of each line of calculation eg *n*($S_2O_3^{2-}$) = … mol

					No credit was given to candidates who grasped the identity of the Group 1 iodate from nowhere and calculated the theoretical relative formula mass.
			Total	**10**	
3 6		i	Titration ✓	1	**IGNORE** type of titration **Examiner's Comments** 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. $C_4H_6O_4 + 2C_2H_6O \rightleftharpoons C_8H_{14}O_4 + 2H_2O$ **Examiner's Comments** 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 **Examiner's Comments** 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.

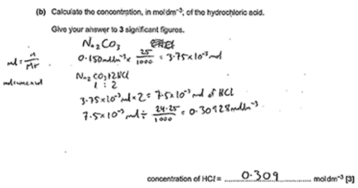
					Even when incorrect, most attempted answers were skeletal formulae.
		iv	Volume cancels **OR** Same number of moles on each side of equation ✓	1	**ALLOW** units cancel **ALLOW** (sum of) balancing numbers/coefficients on each side of equation are the same **OR** same number of (moles of) reactants and 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(**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**	
37			**A**	**1**	**<u>Examiner's Comments</u>** Candidates found this part difficult with many selecting B, the equation that looked a little different, rather than the correct answer of A (a redox equation). This suggests that many candidates are unaware of the role of ammonia as a base.
			Total	**1**	
38		i	Oxidised **AND** (Mg) transfers/loses/donates **2** electrons ✓ **2** essential	**1**	**ALLOW** Mg loses 6 electrons: *3 Mg in equation* **ALLOW** Mg → Mg^{2+} + $2e^-$ **IGNORE** oxidation numbers (even if wrong) **<u>Examiner's Comments</u>** Despite the question clearly asking for a response in terms of the number of electrons transferred, most candidates answered in terms of oxidation number changes. Candidates are recommended to read the question and to answer in terms of its requirements. Underlining 'number of electrons' may have helped candidates to answer the question that had been set.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **IF answer = 2.26 (3 SF) award 3 marks** --- $n(H_3PO_4) = \frac{1.24 \times 50.0}{1000} = 0.062(0)$ (mol) ✓	**3**	At least **3SF** needed throughout **BUT ALLOW** no trailing zeroes (e.g. 0.062 for 0.0620)

			n(Mg) $= \frac{3}{2} \times 0.062(0) = 0.093(0)$ (mol) ✓ **mass of Mg** = 0.0930 × 24.3 = 2.26 (g) ✓ **3 SF required**		**ALLOW ECF** from *n*(H3PO4) **ALLOW ECF** from *n*(Mg) -- **COMMON ERRORS for 2 marks** **3:2 ratio omitted** → *n*(Mg) = 0.062(0) → 1.51 (g) **Inverted 2:3 ratio** → *n*(Mg) = 0.0413 → 1.00 (g) **<u>Examiner's Comments</u>** Most candidates are competent at answering questions based on the mole. Almost all candidates were able to calculate the amount of H3PO4 as 0.062 mol. Candidates then needed to use the 2:3 mole stoichiometric ratio to show that 0.093 mol of Mg reacts, which has a mass of 2.26 g to the required 3 significant figures. The commonest errors were use of the inverse 3:2 ratio to obtain 1.00 g Mg, or to omit the ratio to obtain 1.51 g Mg, as shown in the exemplar. Candidates are advised to show clear working so that credit can be awarded for such responses by applying error carried forward. **Exemplar 1**  (ii) The student plans to add magnesium to 50.0 cm³ of 1.24 mol dm⁻³ H_3PO_4. Calculate the mass of magnesium that the student should add to react exactly with the phosphoric acid. Give your answer to three significant figures. n=cv 50cm³ = 0.05dm³ 1.24 × 0.05 = 0.062 mol 0.062 × 24.3 = 1.5066 g M=n×mr mass of Mg = 1.51 g [3]
		iii	**Separation of solid** Filter to obtain solid/precipitate ✓ *Requires realisation that solid is filtered off.* *Solid may be stated within in 'removal of water'* **Removal of water** Dry (solid) **OR** Evaporate (water/solution/liquid) ✓	2	**ALLOW** **Removal of water** Evaporate/ distil water/solution/liquid ✓ **IGNORE** 'distil' if product **OR** H_2 is distilled **Collection of remaining solid** ✓ *Requires realisation that solid remains*

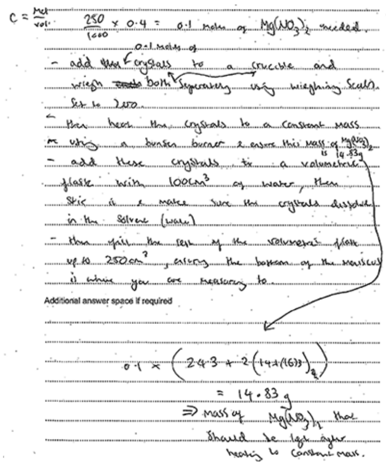
					IGNORE 'Leave to crystallise' *(already solid)* **Examiner's Comments** Candidates often struggle with questions based on practical work. There were many random responses to this question, with relatively few candidates identifying that solid magnesium phosphate could be obtained by filtration, followed by drying.
		iv	**Formula** MgO **OR** $Mg(OH)_2$ **OR** $MgCO_3$ **OR** soluble Mg salt ✓ **Equation** $3MgO + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3H_2O$ **OR** $3Mg(OH)_2 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 6H_2O$ **OR** $3MgCO_3 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3CO_2 + 3H_2O$	**2**	**In equation:** **NO ECF** from incorrect formula **ALLOW** multiples **IGNORE** state symbols (even if incorrect) **Soluble Mg salts** include $MgCl_2$, $MgSO_4$, $Mg(NO_3)_2$, $MgBr_2$, MgI_2 If unsure, check with TL e.g. $3MgCl_2 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 6HCl$ **Examiner's Comments** Candidates were expected to identify a suitable reagent for this reaction, with most choosing magnesium oxide, hydroxide or carbonate. Credit was also given for using a soluble magnesium salt such as its sulfate, chloride or nitrate. The correct equation often followed, but errors sometimes appeared in the form of incorrect formulae, such as MgOH for magnesium hydroxide. The exemplar shows a good clear response, using MgO as the reagent. **Exemplar 2** 
			Total	**8**	
39	a	i	Titre/cm³ | 24.20 | 23.85 | 24.30 | ✓	2 (AO2.4)	**DO NOT ALLOW** 24.2 **OR** 24.3 **Examiner's Comments** Most candidates added correct titres for the

			Correct subtractions to obtain titres **to 2 DP**		three titrations. However, an error made by a quarter of candidates was to omit the zero as the second decimal place in the first and third titres. This should have been usual practice from candidate experience of practical work and has also been highlighted as a common error in previous exam series.
		ii	mean titre = $\frac{24.20 + 22.30}{2}$ = 24.25 (cm^3) ✓ *i.e. using concordant (consistent) titres*	(AO2.4)	**DO NOT ALLOW** mean of all three titres, i.e. $\frac{24.20 + 23.85 + 22.30}{3}$ = 24.10/24.12 **ALLOW ECF** from incorrect concordant titres from 22a(i) **<u>Examiner's Comments</u>** Most candidates identified that the first and third titres were concordant and calculated the mean titre that should be used as 24.25 cm^3. About a third of candidates calculated the mean of all 3 titres as 24.10 or 24.12 cm^3. Normal practice in titrations would be to select the closest titres. **OCR support** The Practical Skills handbook contains guidance on correct practice for recording titration results and calculating average titre values in Appendix 4: Measurements, which can be shared with students: https:/www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf.
	b		**FIRST CHECK THE ANSWER ON ANSWER LINE IF answer = 0.309 (mol dm^{-3}) award 3 marks** -- ***n*(Na_2CO_3)** = $0.150 \times \frac{25.00}{1000}$ = 3.75×10^{-3} (mol) ✓ ***n*(HCl)** = 2 × n(Na_2CO_3) = 7.50×10^{-3} (mol) ✓	3 (AO2.8×3)	**ALLOW 3SF** or more throughout **IGNORE** trailing zeroes, e.g. **ALLOW** 0.075 for 0.00750 -- **ALLOW ECF** from 2 × incorrect *n*(Na_2CO_3)

			[HCl] to 3 SF $= n(\text{HCl}) \times \frac{1000}{\text{mean titre from } \mathbf{b(i)}}$ $= 7.50 \times 10^{-3} \times \frac{1000}{24.25} = 0.309 \text{ (mol dm}^{-3}\text{)}$ ✓ **3 SF** required		**ALLOW ECF** from incorrect n(HCl), **OR** from $n(Na_2CO_3)$ if n(HCl) stage omitted **ALLOW ECF** from incorrect mean titre in **b(ii)** -- **COMMON ERROR for 3 marks** From 24.10 cm^3 (mean of all 3 titres in **b(ii)**), [HCl] = 0.311 (mol dm^{-3}) **<u>Examiner's Comments</u>** **Exemplar 3**  Many candidates were able to calculate the amount of Na_2CO_3 in the titration as 0.00375 mol although a common error was to calculate the amount of Na_2CO_3 in the 250 cm^3 volumetric flask as 0.0375 mol. Most candidates were credited for the amount of HCl: twice their calculated amount of Na_2CO_3. Candidates then need to scale up this value by 1000/mean titre to obtain the concentration as 0.309 mol dm^{-3}, and to quote the answer to 3 significant figures. Many candidates scaled up using 50.0, the burette volume, rather than their mean titre, resulting in a concentration 0.15 or 1.5 mol dm^{-3}. A significant number also rounded their value to 2 rather than 3 significant figures. Candidates are advised to show clear working so that credit can be given for such responses by applying error carried forward. The working shown in this response is clear. Many candidates working was more jumbled, with unreferenced numbers common.
	c		***Pipette:***	2 (AO3.1×2)	**ALLOW** % uncertainties to *1 SF or more, rounded correctly* --

			$\frac{0.04}{25.0} \times 100 = 0.16$ **OR** 0.2 (%) ✓ ***Burette:*** (using any of 3 titres or mean titre), e.g. $\frac{0.05 \times 2}{24.20} \times 100 = 0.41$ **OR** 0.4 (%) ✓ Response does **NOT** need a statement of whether pipette or burette has greater % uncertainty.		Other burette volumes: $\frac{0.05 \times 2}{23.85} \times 100 = 0.42$ **OR** 0.4 (%) $\frac{0.05 \times 2}{24.30} \times 100 = 0.41$ **OR** 0.4 (%) $\frac{0.05 \times 2}{24.25} \times 100 = 0.41$ **OR** 0.4 (%) **ALLOW burette volume of 50 cm^3, i.e.** $\frac{0.05 \times 2}{50} \times 100 = 0.2\%$ **ALLOW ECF** from incorrect titre in **22(a)** **IF BOTH** calculations are ‘correct’ but ×100 is omitted **BOTH** times, **ALLOW** 1 mark **<u>Examiner’s Comments</u>** Most candidates The calculations here should have reflected practical work carried out by candidates. Candidates were expected to realise that the pipette volume involves one measurement requiring the uncertainty of ±0.04 provided being used. As the volume measured by a burette uses two measurements, the uncertainty of ±0.05 must then be doubled to obtain the percentage uncertainty. It was very common for the burette value to be obtained using 0.05 rather than the doubled 0.10; some candidates doubled both uncertainties. Another common error was to use the volume of the burette of 50 cm3 rather than the volume of solution measured in the burette. **OCR support**

					The Practical Skills handbook contains guidance on calculating uncertainties in Appendix 4: Measurements, which can be shared with students: https:/www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf.
			Total	**7**	
4 0			*Please refer to the marking instructions on this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Calculates the correct mass of $Mg(NO_3)_2{\bullet}6H_2O$ or $Mg(NO_3)_2$. **AND** Explains the preparation steps, with most fine detail. *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)** Attempts a calculation which is partly correct. **AND** Outlines the preparation steps, with some fine detail. *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 the calculation but makes little progress or makes errors. **OR** Briefly outlines the preparation steps, which may be incomplete *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.	6(AO2.8×2) (AO2.3×2) (AO2.7×2)	**Indicative scientific points may include:** **Calculation:** $n = \frac{250.0}{1000} \times 0.4000 = \mathbf{0.1(000)}$ (mol) $M(Mg(NO_3)_2{\bullet}6H_2O) = 256.3$ Mass = 0.1000 × 256.3 = **25.63** g **OR** $M(Mg(NO_3)_2) = 148.3$ Mass = **14.83** g **ALLOW** small slip/rounding errors such as errors on M_r (e.g. use of 24 instead of 24.3 for Mg A_r) **Preparation steps (apparatus and method):** • Weigh mass of crystals • Dissolve in (distilled/deionised) water • Transfer to 250 cm^3 volumetric flask • Make up to the mark with more water so that bottom of meniscus is on the mark **IGNORE** removing the water of crystallisation ***Fine detail:*** • 2 or more decimal place balance • Rinse beaker and transfer washings to flask • Use of dropping pipette when filling to mark • Stopper, invert several times to mix

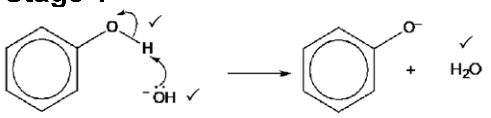
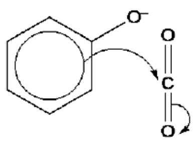
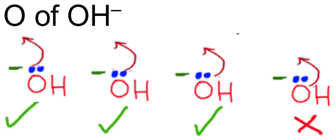
					<u>Examiner's Comments</u> Most candidates focused on removing the water of crystallisation, often going to great depths of explanation, with apparatus diagrams, of how to remove it. Some candidates then went on to explain how to make a standard solution and could be given marks. Calculations for the mass required were often correct or could be given some marks. **Exemplar 3**  $c = \frac{mol}{vol}$ $\frac{250}{1000} \times 0.4 = 0.1$ moles of $Mg(NO_3)_2$ needed. - add the 0.1 moles of crystals to a crucible and wiegh both separately using wieghing scales set to 2d.p. - then heat the crystals to a constant mass using a bunsen burner & ensure this mass of $Mg(NO_3)_2$ is 14.83g - add these crystals to a volumetric flask with 100cm³ of water, then stir it & make sure the crystals dissolve in the solvent (water) - then fill the rest of the volumetric flask up to 250cm³, ensuring the bottom of the meniscus is where you are measuring to. Additional answer space if required $0.1 \times (24.3 + 2(14 + (16)3)_2)$ = 14.83 g ⇒ mass of $Mg(NO_3)_2$ that should be left after heating to constant mass. This in a response of a common approach to this question, it was given 4 marks. Despite calculating the mass properly, the candidate then put all their efforts into describing removing the water of crystallisation and left out the valuable fine detail required for a Level 3 response.
			Total	**6**	
4 1		i	(Titres that agree) within 0.1 cm³ ✓	1 (AO2.3)	**ALLOW** within 0.05 cm³ **ALLOW** ml for cm³ If cm³ units are absent, **ASSUME** cm³ **BUT** **DO NOT ALLOW** incorrect units, e.g. dm³; mol dm⁻³
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 0.0856 (mol dm^{-3}) award 3 marks**	3	**Use ECF throughout** **DO NOT ALLOW** 4.3×10^{-3} **BUT** remaining marks available by **ECF** e.g. $4.3 \times 10^{-3} \div 2 = 2.15 \times 10^{-3}$ ✓ **ECF**

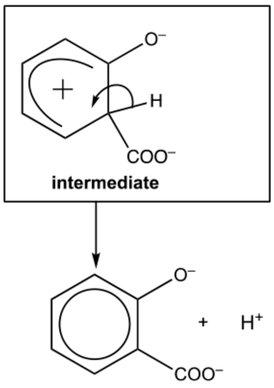
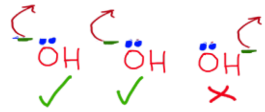
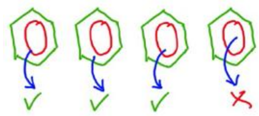
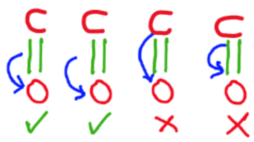
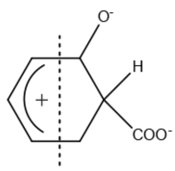
			--- $n(HNO_3) = 0.160 \times \frac{26.75}{1000}$ = 4.28×10^{-3} (mol) ✓ $n(Ba(OH)_2)$ in 25.0 cm^3 = $\frac{4.28 \times 10^{-3}}{2}$ = 2.14×10^{-3} (mol) ✓ Concentration = $2.14 \times 10^{-3} \times \frac{1000}{25}$ = 0.0856 (mol dm^{-3}) ✓	(AO2.8×2) (AO2.4)	$2.15 \times 10^{-3} \times \frac{1000}{25} = 0.086$ ✓ **ECF** **<u>Examiner's Comments</u>** Many candidates seemed to be unfamiliar with the term 'concordant titres'. Acceptable responses were 'within 0.1 cm^3 and within 0.05 cm^3. Common incorrect answers for this important term included 'the closest titres', 'similar titres', 'repeated titres' and 'within 0.5 cm^3'.
			Total	**3**	
4 2		i	**Overall equation AND state symbols:** **M**(s) + 2HCl(aq) → **M**Cl_2(aq) + H_2(g) ✓ **STATE SYMBOLS required in overall equation ONLY** **Half equations:** Oxidation **M → M^{2+}** + 2e$^-$ ✓ Reduction $2H^+ + 2e^- \rightarrow H_2$ **OR** $H^+ + e^- \rightarrow ½H_2$ ✓	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, **ALLOW** M^{+2} for M^{2+} **OR** H^{+1} for H^+ **ALLOW M** – $2e^-$ → **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^+

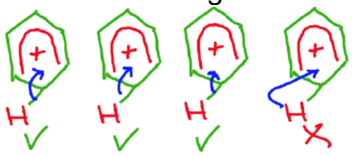
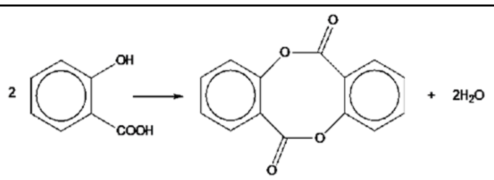
					was used, the half equation was often unbalanced or electrons had been omitted. It is recommended that candidates carefully use the chemical information in the question.
		ii	Bubbles/effervescence/fizzing stops ✓ **M**/metal/solid has disappeared/dissolved ✓	2 (AO 3.3×2)	Responses must imply that all 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) ✓ $n(HCl)$ 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) ✓ $n(HCl)$ that reacted with **M** $= 0.210 - 8.72 \times 10^{-2} = 0.1228$ (mol) ✓	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

			$n(\mathbf{M})$ 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 cm³* *5 marks* 0.210 – 8.72 × **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 × **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		**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**	
43			**D**	1 (AO 2.7)	
			Total	**1**	
44			**D**	1 (AO 2.2)	
			Total	**1**	
45			**D**	1 AO1.1	
			Total	**1**	
46			**B**	1 AO2.3	
			Total	**1**	
47	a		From colourless to pink ✓	1 (AO2.3)	
	b	i	Titre: 18.50, 18.05, 18.20, 18.30 ✓ *All titres with 2 DP and ending with '0' **OR** '5'*	1 (AO2.4)	**DO NOT ALLOW** responses given to only 1 decimal place
		ii	To estimate the titre ✓	1 (AO2.3)	**ALLOW** 'getting a rough idea of the titre' (or similar wording)
		iii	18.25 cm^3 ✓	1 (AO2.4)	
		iv	% uncertainty = $\frac{0.1}{18.05} \times 100 = 0.55$ % ✓	1 (AO2.4)	**ALLOW** ECF from incorrect subtraction in (i) or incorrect mean **ALLOW** calculation from other titre values
	c		**FIRST CHECK THE ANSWER ON ANSWER LINE** If answer = 3 AND *M* = 132(,0)…. award 5	5 (AO2.8×4) (AO3.2)	**ALLOW ECF throughout** **ALLOW ECF** from **(b)(iii)**

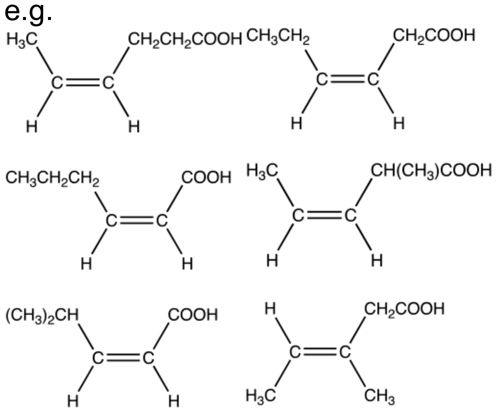
			marks --- n(NaOH) = $\frac{18.25 \times 0.240}{1000}$ = 4.38×10^{-3} ✓ n(acid) in 25 cm^3 = $\frac{4.38 \times 10^{-3}}{2}$ = 2.19×10^{-3} (mol) ✓ n(acid) in 250 cm^3 = 2.19×10^{-2} (mol) ✓ M(acid) = $\frac{2.891}{2.19 \times 10^{-2}}$ = 132(.0)…… (g mol^{-1}) ✓ $M(CH_2)_n$ = 132 – 90 **OR** (132.0…. – 90) **OR** 42 *(seen anywhere)* **AND** n = $\frac{42}{14}$ = 3 ✓ **whole number required**		Answers should be to at least 3 significant figures for first 4 marks.
	d		The titre would be less ✓ Glutaric acid would be less concentrated/more dilute ✓	2 (AO3.3 × 2)	
			Total	**12**	
48		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**	
4 9	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: $Ca_3N_2 + 3H_2O \rightarrow 2NH_3 + 3CaO$ **<u>Examiner's Comments</u>**

					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 ✓ $3CH_3CH(OH)COOH + Al \rightarrow (CH_3CH(OH)COO)_3Al + 1\frac{1}{2} H_2$ 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) **<u>Examiner's Comments</u>** 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**	
50	a		$n(Ba(OH)_2) = 0.150 \times \frac{250}{1000}$ **OR** 0.0375 (mol) ✓ Mass $Ba(OH)_2$ = 0.0375 × 171.3 = 6.42375 (g) ✓ Dissolve solid in (distilled) water (less than 250 cm^3) in beaker ✓ Transfer (solution) to **volumetric** flask **AND** Transfer washings (from beaker) to flask ✓ Make up to mark/up to 250 cm^3 with (distilled) water **AND** Invert flask (several times to ensure mixing) ✓	5 (AO2.4×2) (AO1.2×3)	**ALLOW ECF** from incorrect $n(Ba(OH)_2)$ **ALLOW** 6.42 up to 6.42375 correctly rounded 6.42 g subsumes 1st mark **ALLOW** conical flask for beaker **ALLOW** graduated flask **DO NOT ALLOW** round-bottom or conical flask **Examiner's Comments** required candidates to explain how a standard solution can be prepared and to analyse titration results. Candidates were required to describe how they would prepare 250 cm^3 of a 0.150 mol dm^{-3} standard solution. Most candidates were able to calculate the mass of $Ba(OH)_2$ required by stock mole calculations. Candidates found it more difficult to describe the practical procedure without omissions. Examples included transferring the solution to a volumetric flask but not transferring washings; making the solution up to the graduation mark but not then inverting the flask. Some candidates described how to carry out a titration, rather than preparing the standard solution.

	b			$n(Ba(OH)_2) = 0.150 \times \frac{23.50}{1000}$ = **3.525×10^{-3}** (mol) ✓ n(**D**) in 25.0 cm^3 = $2 \times 3.525 \times 10^{-3}$ = **7.05×10^{-3}** (mol) ✓ n(**D**) in 100 cm^3 = $7.05 \times 10^{-3} \times \frac{100}{25.0}$ = **0.0282** (mol) ✓ **Molar mass** (**D**) $= \frac{3.215}{0.0282}$ = **114** ($g\ mol^{-1}$) ✓ **Formula**: = C_5H_9COOH **OR** C_nH_{2n-1}: $M(C_5H_9) = 114 - 45 = 69$ ✓ *If not stated, could be credited from structure* ***cis* stereoisomers.** The drawn stereoisomers must have • Different groups attached to each C atom of C=C • Each C of C=C has the same group on the same side Any 2 *cis* isomers ✓✓ *Many possibilities*, e.g.  **ALLOW** correct structural, with '*cis*' part displayed **OR** skeletal **OR** displayed formula **OR** mixture of above as long as non-ambiguous **ALLOW** side chains as molecular formula, e.g. C_3H_7 for $(CH_3)_2CH$ **OR** $CH_3CH_2CH_2$ e.g. $C_3H_5O_2$ for CH_2CH_2COOH **IGNORE** poor connectivity to all groups	7 (AO2.8×4) (AO3.2×1) (AO3.2×2)	**Use ECF throughout** Intermediate values for working to **at least 3 SF**. **TAKE CARE** as value written down may be truncated value stored in calculator. Depending on rounding, either can be credited. -- **ALLOW** Mass **D** in 25.0 cm^3 = $\frac{3.215}{4}$ = 0.80375 g **Molar mass** (**D**) = $\frac{0.80375}{7.05 \times 10^{-3}}$ = 114 **COMMON ERRORS:** *Up to Molar mass = 114 (1st 4 marks)* M = 456 → 3/4 marks (mol in 100 cm_3 omitted) $M = \frac{3.215}{7.05 \times 10^{-3}} = 456$ M = 228 → 3/4 marks (*No × 2 for n(D)*) $3.525 \times 10^{-3} \times \frac{100}{25.0} = 0.0141$ $M = \frac{3.215}{0.0141} = 228$ M = 100.8 → 3/4 marks *23.50 instead of 25.00 and scaling by × $\frac{100}{23.50}$* $25.0 \times \frac{0.150}{1000} = 3.75 \times 10^{-3}$ ✗ → $2 \times 3.75 \times 10^{-3} = 7.5 \times 10^{-3}$ ✓ → $7.5 \times 10^{-3} \times \frac{100}{23.50} = 0.0319$ ✓ → $\frac{3.215}{0.0319}$ → 100.8 ✓ **THEN ALLOW ECF** for carboxylic acid closest to calculated M(alkyl group) but must be C_nH_{2n-1} e.g. For ***M(alkyl)* = 100**, **ALLOW** C_4H_7 (55) For ***M(alkyl)* = 411**, **ALLOW** $C_{29}H_{57}$ (405) **OR** $C_{30}H_{59}$ (419) **THEN** judge *cis* isomers with closest match **ALLOW** 1 mark for 2 *trans* isomers shown

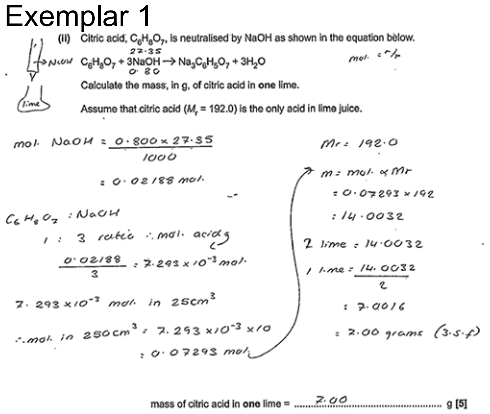
					instead of 2 *cis* isomers ***ECF** for Same error made twice.* **<u>Examiner's Comments</u>** As with Question 2, candidates had more success with the mole calculation in (b) than the descriptive response in (a). Most candidates followed a set procedure to show that the molar mass of the acid was 114, and to then show that the formula must be C_5H_9COOH. Correct cis stereoisomers were seen more rarely. One structure was often repeated in both boxes and the structures seen sometimes had C or H atoms missing. When errors were made with the calculation, these usually stemmed from the scaling up by a factor of 4 in going from 25 cm^3 to 100 cm^3. Some candidates omitted this stage, obtaining a molar mass value of 456. Others scaled up by a factor of 10 to 250 cm^3, obtaining a molar mass of 45.6. Both errors made it very difficult to make further progress. If candidates get into this situation, they are advised to check back through their calculation – it should be obvious that there is a critical error somewhere in the working.
			Total	**12**	
5 1	a		Formula: $CuCO_3$ ✓ $CuCO_3 + 2HNO_3 \rightarrow Cu(NO_3)_2 + CO_2 + H_2O$ ✓	2 (AO1.2) (AO2.6)	**IGNORE state symbols** **ALLOW** formula within equation. **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 --- $n(S_2O_3 2^-) = 0.0200 \times \frac{26.55}{1000}$ = 5.31×10^{-4} (mol) ✓ $n(I_2) = 2.655 \times 10^{-4}$ OR $n(Cu^{2+}) = 5.31 \times 10^{-4}$ (mol) ✓ $m(Cu/Cu^{2+})$ in ore = 63.5 x 5.31×10^{-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+} **<u>Examiner's Comments</u>** 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 Step 2 to a stated volume (e.g. 250 cm^3) OR Repeat titrations **AND** Take mean of concordant/closest titres/ identify anomalies OR	2 (AO3.4x 2)	

			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**	
52	a	i	(Acid) releases H^+ ions/ H^+ donor ✓	1 (AO1.1)	**ALLOW** H^+ **OR** proton **Examiner's Comments** Most candidates scored this mark. Some candidates referred to acids having or containing H^+ ions rather than indicating that H^+ ions are donated or released. A small number of candidates gave simplistic responses in terms of pH only.
		ii	(weak acid) partially dissociates/ionises ✓	1 (AO1.1)	**IGNORE** vague responses that do not imply a number, e.g. • poor proton donor **IGNORE** 'doesn't easily dissociate' **IGNORE** 'strong acid completely dissociates' **Examiner's Comments** Again, this was well answered by most candidates. A few candidates gave responses in terms of pH or indicated that there were more OH^- ions present. **Misconception** Some candidates described a solution with a low concentration of H^+ ions,

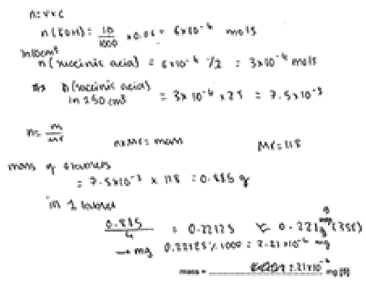
					demonstrating a confusion between concepts of weak and dilute in reference to acids. Visual picture cards can be very helpful in assessing understanding of these concepts. This topic is covered at GCSE and resources can be found here: http:/www.ocr.org.uk/Images/363946-ph-scale-lessonelement.doc
	b	i	<table><tr><th></th><th>Titration 1</th><th>Titration 2</th><th>Titration 3</th></tr><tr><td>Final reading/cm³</td><td>27.35</td><td>27.65</td><td>27.85</td></tr><tr><td>Initial reading/cm³</td><td>0.05</td><td>0.10</td><td>0.45</td></tr><tr><td>Titre/cm³</td><td>27.30</td><td>27.55</td><td>27.40</td></tr></table> ***Initial and final readings*** All titration readings (×6) correct ✓ ***Titres*** Correct subtractions to obtain final titre values ✓ ***Mean titre calculated from concordant results*** Correct mean titre = 27.35 (cm^3) ✓ **Reading recorded to accuracy of burette** All values including mean titre recorded to **two decimal places** with the last figure either **0 or 5** ✓	4 (AO 1.2 × 4)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** missing zeroes throughout except for last marking point e.g. 0.1 for 0.10 **ALLOW ECF** from incorrect burette readings **IF MEAN IS CALCULATED FROM ECF, IT MUST BE FROM CLOSEST TITRES ALLOW any number of decimal places for mean titre for this mark** *Note: Question asks for mean titre to nearest 0.05 cm^3* **<u>Examiner's Comments</u>** Although most candidates gained some marks here, there were a significant number who did not gain all 4 marks. Some candidates need to practice reading burettes and recording their values – this can be checked during practical work. The most common errors included not recording values to 2 decimal places (especially if final number was 0), readings recorded the wrong way round in the table, and misreading 0.05 as 0.5. Most candidates were able to identify concordant results, but some still calculated the mean from all values. This led to an average that needed to be rounded to the nearest 0.05, as asked

					for in the question, resulting in them losing both the mean titre mark and mark for accuracy. Some had errors which lead to values which weren't concordant – this should be a flag to students that they have made a mistake.
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 7.(00) award 5 marks** **---** *n*(NaOH) $= \frac{27.35 \times 0.800}{1000} = 0.02188$ ✓ *n*(A) in 25.0 cm^3 $= \frac{0.02188}{3} = 0.00729(33)$ ✓ *n*(A) in 250 cm^3 = 10 × 0.00729(33) = 0.0729(33) ✓ mass citric acid in 250 cm^3 = 0.0729 × 192 = 14(.0032) (g) ✓ mass citric acid in one lime $= \frac{14.0}{2} = 7.(00)$ (g) ✓	5 (AO 2.8 ×4) (AO 2.4)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **--** ALLOW ECF from incorrect titre calculated in 1(b)(i) Throughout: **ALLOW** 3 SF or more, correctly rounded e.g. *n*(NaOH) = 0.0219 for 0.02188 **ALLOW ECF** from incorrect *n*(NaOH) **ALLOW ECF** for all subsequent steps From *n*(NaOH) = 0.0219, *n*(A) = 0.073(0) *mass* citric acid = 14(.016) *mass* in 1 lime = 7(.008) **Examiner's Comments** Most candidates managed to gain at least 1 mark for this question. The most common mark lost was for not multiplying by 10, having missed that only 25cm^3 of 250 cm^3 citric acid solution was used in the titration. Another mark that was often lost was for not dividing by 2 to find mass in 1 lime rather than the 2 used in experiment. Some candidates used 25cm^3 to calculate their moles of NaOH rather than the titre value from (i). It is vital that candidates are given the opportunity to practice more complex multi-step calculations of this type, with modelling given for lower-attaining candidates. Identifying which information goes with each reactant is vital. All steps in the calculation should be separate and clearly labelled to

					help avoid confusion. Encourage candidates to keep full values in their calculators to avoid intermediate step rounding. When writing down intermediate values, ideally write down the full calculator value or where this is not possible the value must be given to at least 3 significant figures (correctly rounded). It is helpful to the examiner to know if calculator values are used and this could be indicated by using truncated answers followed by … , for example 0.00729… for n(A). Exemplar 1  (ii) Citric acid, $C_6H_8O_7$, is neutralised by NaOH as shown in the equation below. $C_6H_8O_7 + 3NaOH \rightarrow Na_3C_6H_5O_7 + 3H_2O$ Calculate the mass, in g, of citric acid in **one** lime. Assume that citric acid (M_r = 192.0) is the only acid in lime juice. mol. NaOH = 0.800 × 27.35 / 1000 = 0.02188 mol. $C_6H_8O_7$: NaOH 1 : 3 ratio ∴ mol. acid = 0.02188 / 3 = 7.293 × 10^{-3} mol. 7.293 × 10^{-3} mol. in 25 cm^3 ∴ mol. in 250 cm^3 = 7.293 × 10^{-3} × 10 = 0.07293 mol Mr = 192.0 m = mol. × Mr = 0.07293 × 192 = 14.0032 2 lime = 14.0032 1 lime = 14.0032 / 2 = 7.0016 = 7.00 grams (3.s.f) mass of citric acid in **one** lime = 7.00 g [5] The exemplar shows a response where each step of the calculation is shown clearly. The candidate has also used pictures to aid them, recognising that the NaOH is in the burette and lime juice in the conical flask. All values are identified and there is no intermediate rounding. All 5 marks are given here.
	c		**Action taken to modify method** Use half a lime **OR** Make up lime juice (solution) in 1 dm^3 volumetric flask ✓ **Dilution ratio to justify** 4 times less citric acid/lime juice **OR** NaOH is 4 times more dilute (giving same titre) **OR** 1:4 ratio for NaOH concentration ✓	2 (AO 3.4 × 2)	**ALLOW** any feasible method that would give a dilution factor of 4 **ALLOW** quartered **<u>Examiner's Comments</u>** A very challenging question with very few candidates scoring both marks. The response needed a clear indication of how

					the method would be altered and a justification for why this would work. Lots of candidates recognised the need to dilute the citric acid to obtain the correct titre but were not able to give a method of how to do this or any indication of quantities needed. Some candidates said to use a larger volume of NaOH – not recognising that this would be the titre value, e.g. "in order to keep the same titre but lower concentration of NaOH the student should titre more NaOH". Some gave the method of how to dilute the NaOH or even just said to add water. A few suggested using a higher concentration of lime juice. Candidates need to be given opportunities to plan practical work to fully appreciate the impact that any changes will have (specification 1.1.1). **OCR support** Further information about practical skills assessed on written exams can be found in section 3 of the practical skills handbook - https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf. If using our suggested practicals, then encourage candidates to answer the extension opportunity questions to help develop a deeper understanding in preparation for written assessments.
			Total	**13**	
5 3		i	**Titres** 22.75 | 22.45 | **22.70** | 22.55 ✓ **Mean titre** $\frac{22.45 + 22.55}{2}$ = 22.5(0) (cm^3) ✓	2 (AO1.2×2)	**2 DP essential** i.e. last 0 for 22.70 **DO NOT ALLOW** use of trial titre. **Examiner's Comments** Almost all candidates calculated the titres correctly, but a significant number were penalised for recording 22.70 as 22.7. A significant number also used this result and the trial titre to derive their mean value.

					There were also very small numbers of candidates who used all 4, or all of titres 1, 2 and 3, to calculate their mean. **OCR support** Links to the legacy coursework tasks and PAG practice question sets can be found on OCR Interchange. Exam hints for students can be found at: https:/www.ocr.org.uk/Images/592305-exam-hints-for-students.pdf.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 498 mg award 5 marks -- **Number of moles of KOH in titre** $= \frac{1.35 \times 10^{-3}}{2}$ **OR** 1.35×10^{-3} (mol) ✓ **Number of moles of acid in 10 cm^3** $= \frac{1.35 \times 10^{-3}}{2}$ **OR** 6.75×10^{-4} (mol) ✓ ***Number of moles of* acid in 250 cm^3** $= 6.75 \times 10^{-4} \times 25$ **OR** 0.016875 (mol) ✓ ***Mass of* acid in 4 tablets** $= 0.016875 \times 118$ **OR** 1.99125 (g) ✓ **Mass in one tablet AND mg conversion** (i.e. divide by 4 **AND** x 1000) $= \frac{1.99 \times 10^{3}}{4}$ =498 (mg)✓ **Answer must be to 3SF**	5 (AO2.8×3) (AO3.1) (AO3.2)	**ALLOW ECF** from incorrect titre in 19 (a) (i) **ALLOW ECF** throughout **TAKE CARE: values shown may be truncated calculator values.** Steps can be calculated in any order which will change the intermediate answers. Marks are for the processing of the data. **ALLOW 3SF** up to calculated value throughout **BUT** ignore trailing zeros on intermediate values **IGNORE** rounding errors past **3SF** -- **Common errors** **5 marks** 503 mg (use of 22.725 cm^3) **4 marks** 996mg (no divided by 2) 19.9mg (no volume conversion i.e. x 25) **<u>Examiner's Comments</u>** Candidates made good progress with this calculation, many gaining 4 or 5 marks, including error carried forward from incorrect titres. Common errors included, in various combinations: not converting the final answer into mg, not converting volume to dm^3, missed ratio, multiplying the moles in 10cm^3 acid by 10 instead of 25 and/or wrong M_r. Responses to Question 19 (a) (ii) often featured rows of figures and random sums without a single word about what the figures, or sums, were set to calculate.

					Candidates should remember to provide written indications of what it is they are working out – presenting the calculations without any annotations can make it harder for error carried forward marks to be given if there is an error in their calculation. **Exemplar 1**  The exemplar here shows a good use of annotation. There is a clear indication of the mathematical process so that the error carried forward is easily identified and the candidate gains the method marks
			Total	**7**	
5 4		i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 731(g) award 3 marks** **--** ***n*(Z)** $n(Ca_5NH_4(NO_3)_{11}{\bullet}10H_2O) = \frac{1500}{1080.5}$ **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 ✓	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

			mass limestone = $\frac{694.8 \times 100}{95.0}$ = 731 g (**3SF**) ✓		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) → $3MgCl_2$(aq) + $CaCl_2$(aq)+ $4H_2O$(l) + $4CO_2$(g) Correct formulae ✓ Balanced **AND** state symbols ✓	2 (AO2.6×2)	**ALLOW** multiples **M2** dependent on **M1** **IGNORE** incorrect state symbol for $Mg_3Ca(CO_3)_4$ **<u>Examiner's Comments</u>** 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	**5**	
55			**D**	1(AO1.1)	**<u>Examiner's Comments</u>** Candidates were less successful with this question than Questions 1 and 2, and it appeared as if many candidates did not recognise that ammonia was an alkali. Most candidates rejected A but a significant number selected C, suggesting that they did not recognise HNO_3 as an acid or confused HNO_3 with NH_3.
			Total	**1**	
56	a		(Strong acid) completely/fully dissociates/ionises ✓	1 (AO1.1)	**DO NOT ALLOW** easily dissociates **ALLOW** **ALL** H^+ ions are released **<u>Examiner's Comments</u>** Most candidates knew that a strong acid completely dissociates. Only the lower-

					attaining candidates responded in terms of a low pH.
	b	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.
	c	i	Volumetric flask ✓	1 (AO1.2)	**ALLOW** graduated flask **<u>Examiner's Comments</u>** Most candidates recognised that a volumetric flask is used to accurately prepare volumes of solutions. A common error was a conical flask, perhaps by not reading the information clearly and giving

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>the name of the flask used in the titration itself.</td></tr>
<tr><td></td><td></td><td>ii</td><td><table><tr><td>Final reading/cm^3</td><td>20.25</td><td>40.85</td><td>25.85</td></tr><tr><td>Initial reading/cm^3</td><td>0.00</td><td>20.25</td><td>5.50</td></tr><tr><td>Titre/cm^3</td><td>20.25</td><td>20.60</td><td>20.35</td></tr></table>All 3 titres correct to 2 DP ✓</td><td>1
(AO1.2)</td><td>DO NOT ALLOW 1 DP, e.g. 20.6 instead of 20.60

<u>Examiner's Comments</u>

Most candidates were able to work out these simple subtractions. Candidates were told that the titration readings were read to the nearest 0.05 cm^3, requiring titres to be shown to two decimal places, which includes a '0'. The middle titre is therefore 20.60 cm^3 and not 20.6 cm^3, which continues to be the commonest error seen.</td></tr>
<tr><td></td><td></td><td>iii</td><td>mean titre = $\frac{20.25 + 20.35}{2}$ = 20.30 (cm^3) ✓
i.e. using concordant (consistent) titres</td><td>1
(AO2.8)</td><td>ALLOW 20.3
Missing '0' already penalised in c(ii)

DO NOT ALLOW mean of all three titres,

i.e. $\frac{20.25 + 20.60 + 20.35}{3}$ = 20.40

<u>Examiner's Comments</u>

Candidates are expected to use only concordant titres when working out the mean titre and the middle titre of 20.60 cm^3 should be rejected. Most candidates did this to produce 20.30 cm^3 as their mean titre. Predictably, the commonest error was to use all three titres to produce the incorrect mean of 20.40 cm^3.</td></tr>
<tr><td></td><td></td><td>iv</td><td>$n(H_2SO_4) = 0.165 \times \frac{20.30}{1000} = 3.5 \times 10^{-3}$ (mol) ✓
n(MOH) in 25.0 cm^3 $= 2 \times 3.35 \times 10^{-3}$
$= 6.70 \times 10^{-3}$ (mol) ✓
n(MOH) in 250.0 cm^3 $= 10 \times 6.70 \times 10^{-3}$
$= 6.70 \times 10^{-2}$ (mol) ✓</td><td>4
(AO3.1 ×3)
(AO3.2 ×1)</td><td>ALLOW ECF throughout and from incorrect concordant titres from 22c(iii)

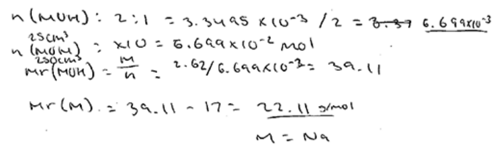
Calculator value = 3.3495×10^{-3}

Calculator value = 6.699×10^{-3}

Calculator value = 6.699×10^{-2}

By ECF, ALLOW Group 1 metal nearest to calculated value of A_r</td></tr>
</table>

			A_r of **M** = $\frac{2.62}{6.70 \times 10^{-2}}$ × 10^{-2} = 39.1 **AND M** = potassium/K ✓		**COMMON ERRORS** **Use of 20.4 from mean of all 3 titres ALL 4 MARKS** $n(H_2SO_4)$ = 0.165 × $\frac{20.4}{1000}$ = 3.366 × 10^{-3} (mol) ✓ from **(c)(iii)** n(**M**OH) in 25.0 cm^3 = 2 × 3.366 × 10^{-3} = 6.732 × 10^{-3} (mol) ✓ n(**M**OH) in 250.0 cm^3 = 10 × 6.732 × 10^{-3} = 6.732 × 10^{-2} (mol) ✓ A_r of **M** = $\frac{2.62}{6.732 \times 10^{-2}}$ = 38.9…. **OR 39 AND M** = K ✓ **IF** ×10 is absent, A_r = 389 **AND M** = Cs **OR** Fr **Use of 25.0 (wrong volume) for $n(H_2SO_4)$** $n(H_2SO_4)$ = 0.165 × $\frac{25}{1000}$ = 4.125 × 10^{-3} (mol) ✗ n(**M**OH) in 25.0 cm^3 = 2 × 4.125 × 10^{-3} = 8.25 × 10^{-3} (mol) ✓ n(**M**OH) in 250.0 cm^3 = 10 × 8.25 × 10^{-3} = 8.25 × 10^{-2} (mol) ✓ A_r of **M** = $\frac{2.62}{8.25 \times 10^{-2}}$ = 31.75.....**AND M** = K ✓ **IF** ×10 is absent, A_r = 317.5 **AND M** = Cs **OR** Fr **<u>Examiner's Comments</u>** Many candidates followed a well drilled method to identify the unknown metal M as potassium: • Moles of H_2SO_4 in the mean titre • Moles of KOH in 25 cm^3 • Scaling ×10 for moles of KOH in 250 cm^3 • Molar mass of the metal as 39.11 and identified as K. A number of candidates omitted the scaling stage to obtain a molar mass of 391.1. By

					ECF, the 'correct' identity would be caesium or francium. Some candidates then 'fiddled' their response, dividing by 10 to 'identify' the metal as K. This incorrect approach was not credited. Exemplar 2  A common error, illustrated in Exemplar 2, was for candidates to calculate 39.11 but to think that this was the mass of MOH and not M. They then subtracted 17 (for OH) from 39.11 to obtain a response of 22.11 and identified M as sodium instead of potassium. This error probably stems from candidates either not reading the question closely enough or confusion about the mole concept.
			Total	**11**	
57			**C**	1 (AO 2.2)	**Examiner's Comments** This question was answered correctly for the most part with the answer being C.
			Total	**1**	
58	a	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 **Examiner's Comments** 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		2 (AO 3.1 ×	**ALLOW** ORA

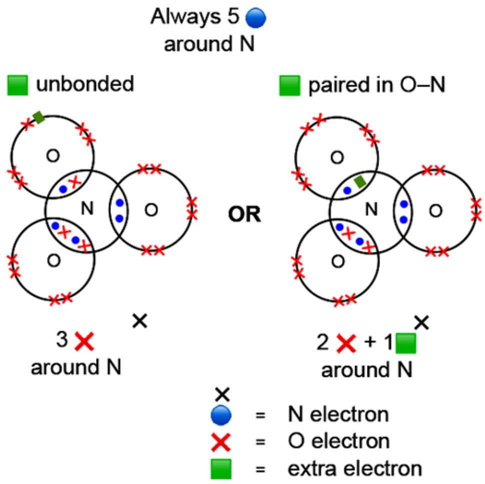
			M_r of $SrCO_3$ is different to M_r $CaCO_3$ / moles $SrCO_3$ are different to moles $CaCO_3$ ✓ M_r of $SrCO_3$ > M_r $CaCO_3$ / moles $SrCO_3$ < moles $CaCO_3$ **AND** **More** moles/volume gas (from $CaCO_3$)✓	1) (AO 3.2 × 1)	**ALLOW** n($SrCO_3$) = (1.00 ÷ 147.6) = 6.78 × 10^{-3} (mol) **AND** n($CaCO_3$) = (1.00 ÷ 100.1) = 9.99 × 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 ÷ 147.6) = 6.78 × 10^{-3} (mol) **AND** n($CaCO_3$) = (1.00 ÷ 100.1) = 9.99 × 10^{-3} (mol) **AND** Calculated values (CO_2) 163 cm^3 **AND** 240 cm^3 **Examiner's Comments** 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.
	b	i	$Mg + 2H^+ \rightarrow Mg^{2+} + H_2$ ✓	1 (AO 2.6)	**ALLOW** multiples **ALLOW** Mg^{+2} **IGNORE** state symbols **Examiner's Comments** Ionic equations still present candidates with a challenge. A few candidates scored the mark but many candidates gave a full

					equation or one that contained a mismatch of spectator ions as well as the correct ions.
		ii	HC*l* is a strong acid/completely dissociates **AND** CH_3COOH is a weak acid/partially dissociates ✓ Greater H^+ concentration in HC*l* **AND** More frequent collisions / faster rate of reaction ✓ More CH_3COOH dissociates until same number of moles of H^+ released **OR** same total moles H^+ produced (by the end) **OR** (Both acids are monobasic) and have the same number of moles of acid ✓	3 (AO 1.1 × 1) (AO 3.1 × 2)	**IGNORE** HCl is a strong**<u>er</u>** acid than ethanoic acid. **ALLOW** ORA **DO NOT ALLOW** dibasic/tribasic **<u>Examiner's Comments</u>** This question proved challenging for the candidates to identify the three ideas: Those of comparing acids, comparing moles and comparing rates. Very few candidates were able to score the 3 marks. Most candidates recognised the different strength of the two acids, but some only used comparative language. Some linked the moles of acid used to the volume of gas produced but many simply restated the same volume and concentration which is given within the question. Only a few candidates linked the higher initial [H^+] in HCl to the increased rate through more frequent collisions. A common issue was describing the rate of dissociation rather than the [H^+] present in determining the rate of the reactions or mentioning that it dissociates more but not linking this to the H+ concentration.
			Total	**7**	
59			**FIRST CHECK THE ANSWER ON ANSWER LINE** **If Mass = 318 (mg) award 6 marks** -- **Mean titre** **1 mark** $= \frac{(22.30 + 22.40)}{2}$ = 22.35(0) (cm^3) ✓	6 (AO 2.8 ×6)	***FULL ANNOTATIONS MUST BE USED*** -- **Common error:** Incorrect mean from all 3 titres = 22.6 cm^3 **CHECK BELOW TITRATION TABLE** **Use ECF throughout** Intermediate values for working to **at least 3 SF.**

			Analysis of results 5 marks n(HCl) = 0.200 × $\frac{22.35}{1000}$ = 4.47 × 10^{-3} (mol) ✓ n(NaOH) remaining in 25.0 cm^3 = n(HCl) n(NaOH) remaining in 250 cm^3 = 4.47 × 10^{-3} × 10 = 4.47 × 10^{-2} **OR** 0.0447 (mol) ✓ n(NaOH) that reacted with **aspirin** = 0.0500 – 4.47 × 10^{-2} = 5.30 × 10^{-3} (mol) ✓ mass in 3 tablets = 5.30 × 10^{-3} × 180 = 0.954 g ✓ Mass in 1 tablet = 318 mg ✓		**ALLOW** scaling for 1 aspirin tablet early in calc, e.g. for final 2 marks: n(aspirin) in 1 tablet = $\frac{5.30 \times 10^{-3}}{3}$ = 1.77..... × 10^{-3} (mol) ✓ Mass in 1 tablet = 1.77..... ✓ 10^{-3} × 180 = 0.318 g = 318 mg ✓ **COMMON ERRORS:** *No scaling × 10* 0.05 – 4.47 × 10^{-3} → 4.553 × 10^{-2} ✓ 4.553 × 10^{-2} × 180 → 8.1954 g in 3 tablets ✓ → **2731.8/2732/2730 mg** in 1 tablet ✓ *5 marks* -- *No scaling × 10 before subtraction but scaling after 4 marks* 0.05 – 4.47 × 10^{-3} → 4.553 × 10^{-2} ✓ 4.553 × 10^{-2} × 10 × 180 → 81954 g in 3 tablets ✗ → **27318 / 27320 / 27300 mg** in 1 tablet ✓ -- *No subtraction from 0.05* *5 marks* → 4.47 × 10^{-2} × 180 → 8.046 → **2682/2680 mg** in 1 tablet -- *Omitting initial titration calculation* *2 marks* 0.05 × 180 → 9 g in 3 tablets ✓ → **3000 mg** in 1 tablet ✓ --

					Mean of 22.60 (use of all 3 titres) *5 marks* Mean = 67.8/3 = 22.60 ✗ → 4.52×10^{-3} ✓×10 → 4.52×10^{-2} ✓ $0.05 - 4.52 \times 10^{-2}$ → 4.80×10^{-3} ✓ $4.80 \times 10^{-3} \times 180$ → 0.864 g in 3 tablets ✓ → **288 mg** in 1 tablet ✓ **<u>Examiner's Comments</u>** Compared with the application based Question 4, candidates answered this stock titration calculation well. Almost all candidates determined that the mean titre was 22.35 cm^3 and went on to calculate the number of moles of HC*l* as 4.47×10^{-3} mol. Most scaled this value by 10 to determine the moles in 250 cm^3. Most candidates then used the initial moles of HCl to determine the moles of aspirin in the 3 tablets as 5.30×10^{-3} moles. A significant number omitted this stage but they were able to be credited for the next stage of calculation using a correct method. Consequently over half the candidates were awarded 5 or 6 marks for this stock calculation.
			Total	**6**	
60	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*	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'

			O–N–O 120° ✓ 3 bonded regions/pairs (around N) ✓ *Independent of bond angle*		**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	 8 Electrons around N as above **1st mark:** 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**	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 **× × • •** **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

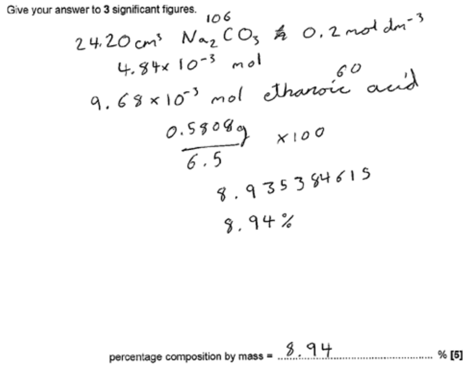
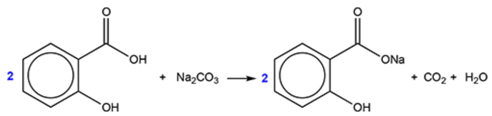
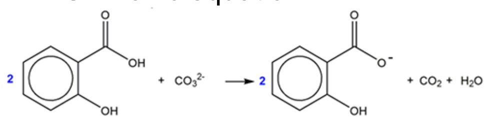
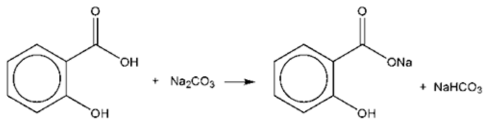
					oxygen electrons and the extra electron. Then the remaining oxygen electrons could be added, taking care that there were 6 around out O atom. Finally the extra electron would need to be placed in an octet gap. Many candidates showed just 4 nitrogen electrons and this approach resulted in no marks. Other 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**	
6 1			2 Ba + O_2 → 2 BaO ✓ BaO + H_2O → $Ba(OH)_2$ ✓ Neutralisation **OR** acid-base ✓	3	**ALLOW** multiples **IGNORE** state symbols, even if incorrect **ALLOW** Ba + H_2O → 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**	
6 2	a		strong acid: **fully dissociates/ionises** **AND** weak acid: **partially dissociates/ionises** ✓	1	**ALLOW** strong acid fully dissociates weak acid dissociates/ionises **less** **ALLOW** strong acid releases all H^+ ions weak acid partially releases H^+ ions **IGNORE** strrong acid dissociates more strrong acid dissociates quicker **DO NOT ALLOW** strong acid fully dissociates weak acid does not fully dissociate ***Response does not state that weak acid dissociates*** **IGNORE** breaks down for dissociate/ionise **DO NOT ALLOW** comparison of concentrations **<u>Examiner's Comments</u>** Most candidates described a strong and a weak acid in terms of dissociation or ionisation, with few just describing one of the two types of acid.
	b	i	Titre/cm^3 | 24.40 | 24.15 | 24.25 | ✓ Correct subtractions to obtain titres **to 2 DP**	1	**DO NOT ALLOW** 24.4 **<u>Examiner's Comments</u>** Most candidates were able to work out these simple subtractions. Candidates were told that the titration readings were read to the nearest 0.05 cm^3, requiring volumes to be recorded to two decimal places, which may include a '0'. The right-hand initial reading is therefore 24.10cm^3 and not 24.1 cm^3, which continues to be the commonest error seen.
		ii	mean titre = $\frac{24.15 + 24.25}{2}$ = 24.20 (cm^3) ✓ *i.e. using concordant (consistent) titres*	1	**ALLOW** 24.2 *DP already assessed in b(i)*

					DO NOT ALLOW mean of all three titres, i.e. $\frac{24.40 + 24.15 + 24.25}{3}$ = 24.26/24.27 **ALLOW ECF** from incorrect concordant titres from **22b(i)** **<u>Examiner's Comments</u>** Candidates are expected to use only concordant titres when working out the mean titre and the left-hand titre of 24.40cm^3 should be rejected. Most candidates did this to produce 24.20 cm^3 as their mean titre. Use of 24.2 was allowed because rounding of a '0' as the second decimal place had already been penalised in Question 21 (b) (i). Predictably, the most common error was to use all three titres to produce the incorrect mean of 20.27cm^3.
		iii	**FIRST CHECK ANSWER ON ANSWER LINE** **IF answer = 89.4 (%) award 5 marks** **CHECK** mean titre from **22b(ii)** first. **THEN** apply **ECF** throughout using THIS mean titre **First 3 mark must come from the titration** ***n*(Na_2CO_3)** $= 0.200 \times \frac{24.20}{1000}$ = 4.84 × 10^{-3} (mol) ✓ ***n*(CH_3COOH) in 25.0 cm^3** = 2 × 4.84 × 10^{-3} = 9.68 × 10^{-3} (mol) ✓ ***n*(CH_3COOH) in 250 cm^3** = 10 × 9.68 × 10^{-3} = 9.68 × 10^{-2} (mol) ✓ **mass of CH_3COOH in 250 cm^3**	5	**ALLOW** 3**SF** or more throughout **IGNORE** trailing zeroes, e.g. **ALLOW** 24.2 for 24.20 **ALLOW ECF** from incorrect mean titre in **b(ii)** **ALLOW ECF** from 2 × incorrect *n*(Na_2CO_3) **ALLOW ECF** from incorrect *n*(CH_3COOH), **OR** from *n*(Na_2CO_3) if *n*(CH_3COOH) stage omitted <u>**ALLOW** 5.81 (3 SF)</u> **IF** mass is rounded to 5.81, Answer is still 89.4% *Calculator = 89.38461538* *8.94% is 4 marks (omission of × 10 stage)* **IF** incorrect mean titre of 24.26/24.27 cm^3 used: *(mean of all 3 titres in **b(ii)**)*, % composition = 89.6% to 3 SF for **ALL** 5 marks by **ECF**

			$= 60 \times 9.68 \times 10^{-2}$ = 5.808 (g) ✓ **% composition to 3 SF** $= \frac{5.808}{6.50} \times 100$ = 89.4 (%) ✓ **3 SF** *Calculator: 89.35384615* **COMMON ERRORS** **Omitting ÷ 1000 for *n*(Na_2CO_3)** *Up to 3 marks are possible* ***n*(Na_2CO_3)** $= 0.200 \times 24.20$ = 4.84 (mol) × ***n*(CH_3COOH) in 25.0 cm³** $= 2 \times 4.84$ = 9.68 (mol) ✓ ***n*(CH_3COOH) in 250 cm³** $= 10 \times 9.68$ = 96.8 (mol) ✓ **mass of CH_3COOH in 250 cm³** $= 60 \times 96.8$ = 5808 (g) ✓ **% composition to 3 SF** $= \frac{5808}{6.50} \times 100$ = 89400 (%) ×		-- **NOTE**: Some candidates are calculating *n*(CH_3COOH) based on the 6.50 g sample being pure **DO NOT ALLOW 0.108(3……** $n(CH_3COOH) = \frac{6.50}{60} = 0.108(3……$ **COMMON ERRORS** **Using 25.0 cm³ (pipette volume) instead of 24.20 cm³** *Up to 4 marks are possible* ***n*(Na_2CO_3)** $= 0.200 \times \frac{25.00}{1000}$ = 5.00×10^{-3} (mol) × ***n*(CH_3COOH) in 25.0 cm³** $= 2 \times 5.00 \times 10^{-3}$ = 1×10^{-2} (mol) ✓ ***n*(CH_3COOH) in 250 cm³** $= 10 \times 1 \times 10^{-2}$ = 1×10^{-1} (mol) ✓ **mass of CH_3COOH in 250 cm³** $= 60 \times 1 \times 10^{-2}$ = 6.00 (g) ✓ **% composition to 3 SF** $= \frac{6.00}{6.50} \times 100 = 92.3$ (%) ✓ *Calculator: 92.30769231* **Examiner's Comments** Many candidates followed a well drilled method to analyse their titration results: • Moles of Na_2CO_3 in the mean titre

				Impossible value		• Moles of CH_3COOH in 25 cm^3 • Scaling ×10 for moles of CH_3COOH in 250 cm^3 Candidates then needed to process their titration results further to determine the percentage composition: • Mass of CH_3COOH in 250 cm^3 • Percentage composition of CH_3COOH to 3 significant figures. Most candidates were able to make some progress through the analysis. Common errors included: • Not ×2 to obtain the moles of CH_3COOH • Omission of the scaling stage. Some candidates ignored the titration results entirely, instead calculating the number of moles of CH_3COOH in 6.5 g of the descaler as 0.1083 mol by assuming that all of the descaler was CH_3COOH. This approach was flawed and could not be given any marks. A final comment must be made about the presentation of many of the responses. Numbers had often been sprayed across the page and it could be difficult to see how these related to a cohesive solution. It was often impossible to give marks for such responses. The question discriminated extremely well with some candidates given all 5 marks. Less successful responses demonstrated problems with approaching this type of question and some were given no marks at all. Exemplar 1

					 Give your answer to 3 significant figures. 24.20 cm³ Na_2CO_3 0.2 mol dm⁻³ 106 4.84×10⁻³ mol 9.68×10⁻³ mol ethanoic acid 60 0.5808g / 6.5 ×100 8.935384615 8.94% percentage composition by mass = 8.94 % [5] Exemplar 1 shows a well-presented response, with the only error being not scaling the moles of CH_3COOH from 25 to 250 cm^3. The result is a percentage composition of 8.94 % instead of 89.4%. The clear presentation allowed the examiner to follow how the incorrect response had been obtained. Error carried forward allowed marks can be given for a correct method, giving a total of 4 out of 5 marks.
			Total	**8**	
6 3		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 **<u>Examiner's Comments</u>**

					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 **Examiner's Comments** 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 4			**Calculation** ***2 marks***	5	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF throughout** ---

			$n(Cu(NO_3)_2{\bullet}3H_2O) = 0.200 \times \frac{100}{1000}$ **OR** 2(.00) × 10^{-2} (mol) **OR** 0.02(00) ✓ Mass $Cu(NO_3)_2{\cdot}3H_2O = 2.00 \times 10^{-2} \times 241.5 =$ **4.83** (g) ✓ **2 or more DP to match balances** **Method** ***3 marks*** **Dissolve** solid in (distilled) **water** (less than 100 cm^3) (in beaker) ✓ Transfer (solution) to **volumetric** flask **AND** Wash/rinse (from beaker to flask) ✓ Make up to mark/up to 100 cm^3 with (distilled water) **AND** Invert flask (several times to ensure mixing) ✓		**ALLOW ECF** from incorrect $n(Cu(NO_3)_2{\bullet}3H_2O)$ 4.83 g subsumes 1st mark **ALLOW** small amount/some **DO NOT ALLOW** 100 cm^3 or more of water **IGNORE** solvent **ALLOW** graduated flask **ASSUME** that wash/rinse is to a volumetric flask **ALLOW** swirl/shake -- **ALLOW** preparation of solutions > 100 cm^3 **4 marks** e.g. for 250 cm^3 $n(Cu(NO_3)_2{\bullet}3H_2O) = 0.200 \times \frac{250}{1000}$ **OR** 0.05 (mol) ✗ Mass $Cu(NO_3)_2{\bullet}3H_2O = 0.05 \times 241.5 =$ **12.075** (g) ✓ Then method adapted for 250 cm^3 volumetric flask e.g. Make up to 250 cm^3 with water **<u>Examiner's Comments</u>** This question differentiated between candidates extremely well. See Exemplar 1 below. Exemplar 1 0.2 mol dm^{-3} 0.2 x 0.1 = 0.02 moll in 100 cm^3 mr = 63.5 + 28 + 96 + 54 = 241.5 241.5 x 0.02 = 4.83g Using 4.83g of $Cu(NO_3)_2 \cdot 3H_2O$, measured using a mass balance to 2 dp. Add this to a beaker and add enough distilled water to dissolve the solid. Use distilled water to wash the boat that you used to measure the copper nitrate into the beaker as well. Pour the solution into a volumetric flask, again washing the beaker with distilled water. Add distilled water to the flask until you reach the 100 cm^3 mark. Put the stopper on and invert slowly several times.

					Exemplar 1 has been included to demonstrate a superb response. The comments that follow highlight some of the issues encountered in the responses. Unfortunately, nearly a quarter of candidates could not be given any marks at all for their responses. To improve, it is worth studying Exemplar 1. The candidate has communicated the key steps required to prepare the standard solution: • Calculation of the mass of hydrated copper(II) nitrate required. • Dissolving the hydrated copper(II) nitrate in water in a suitable container (a beaker). • Transferring the solid to a 100 cm^3 volumetric flask, washing the beaker with water and transferring the washings also to the volumetric flask. • Making the solution up to the 100 cm^3 mark in the volumetric flask and inverting the flask to mix the contents thoroughly. Issues with responses which arose by not reading the question closely enough: • Omitting to calculate the mass of hydrated copper(II) nitrate required. • Calculating the mass of anhydrous copper(II) nitrate instead of the hydrated salt. • Dissolving in 100 cm^3 of water and then adding more water for rinsing. • Not rinsing out the original container at all. • Making the solution up in the volumetric flask. • Using of a 250 cm^3 volumetric flask for preparing 100 cm^3 of solution. • Omitting the inversion stage. • Answering a different question, e.g. how to carry out a titration, how to determine an enthalpy change, how to work out the number of waters of

					crystallisation by heating in a crucible.
			Total	**5**	