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

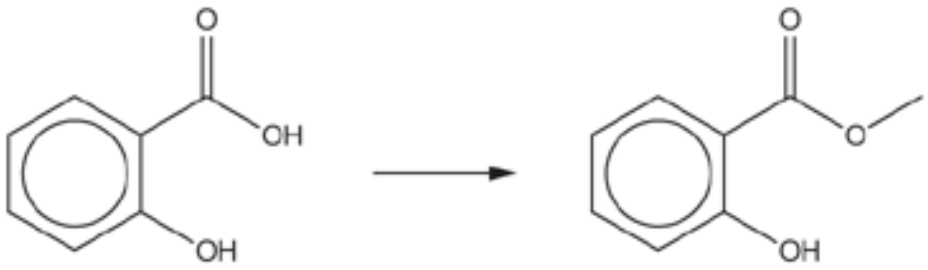
The student needs to prepare a standard solution of $Cu(NO_3)_2 \cdot 3H_2O$ with a concentration of 0.200 mol dm^{-3}. The student has access to usual laboratory apparatus and equipment.

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

[5]

2. 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.

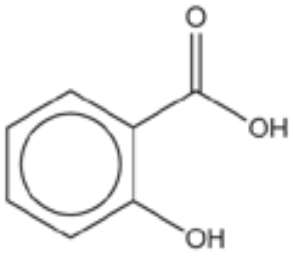
The student follows this method and obtains 5.32 g of pure compound **H**.

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]

3(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]**

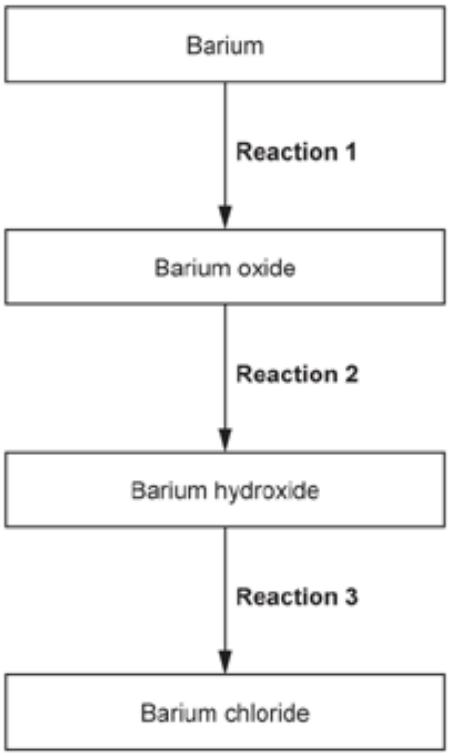
iii. Calculate the percentage composition by mass of CH_3COOH in the descaler.

Assume that CH_3COOH is the only acid in the descaler.

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

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

4. 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**.

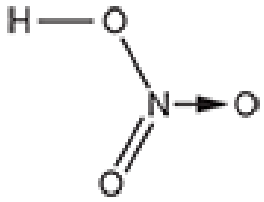
Reaction 1: equation _____

Reaction 2: equation _____

Reaction 3: type of reaction _____ **[3]**

5(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^-.

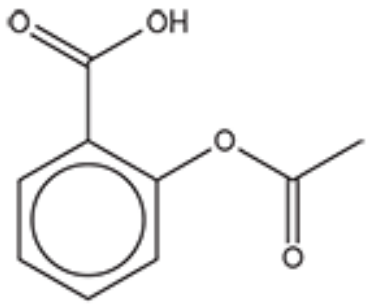
Draw a 'dot-and-cross' diagram for the NO_3^- ion.

Use a different symbol for the extra electron.

[2]

6. 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]**

7(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, HC*l*.

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]

8. 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} HC*l* and 0.0200 mol dm^{-3} NaC*l*
B 0.0200 mol dm^{-3} HC*l* and 0.0400 mol dm^{-3} NaC*l*
C 0.0200 mol dm^{-3} HC*l* and 0.0600 mol dm^{-3} NaC*l*
D 0.0600 mol dm^{-3} HC*l* and 0.0200 mol dm^{-3} NaC*l*

Your answer ☐ **[1]**

9(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.

$2\mathbf{M}OH(aq) + H_2SO_4(aq) \rightarrow \mathbf{M}_2SO_4(aq) + 2H_2O(l)$

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]**

10. Which compound is an alkali?

A CH_3COOH
B CH_3OH
C HNO_3
D NH_3

Your answer ☐ **[1]**

11. 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]**

12. 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]

13(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?**

---

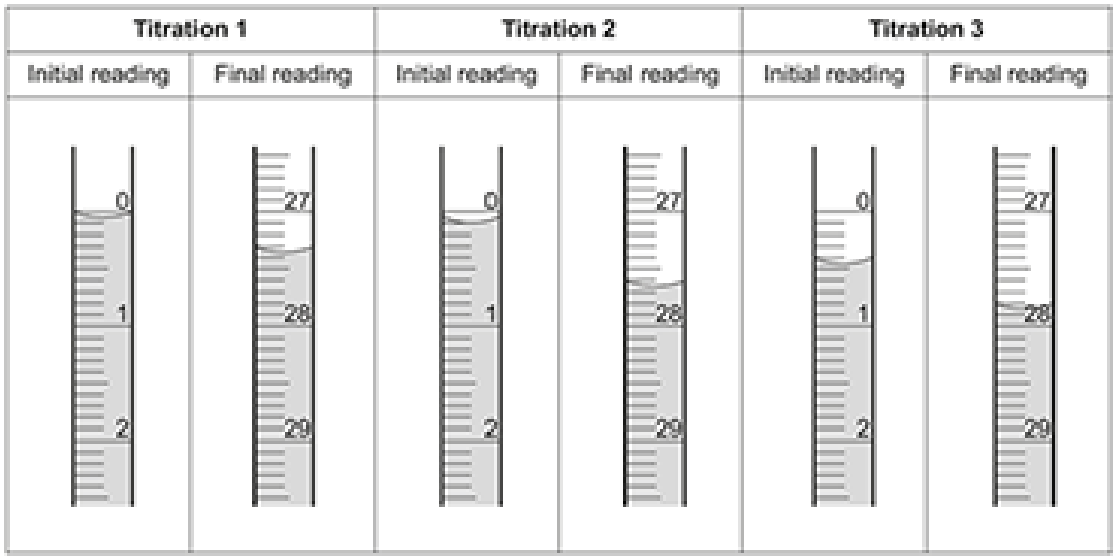
[1]

(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 250.0cm^3 volumetric flask and make up to the mark with distilled water.
- Pipette 25.0cm^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]

END OF QUESTION PAPER