



Cambridge International AS & A Level

CANDIDATE
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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

May/June 2022

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has **12** pages. Any blank pages are indicated.



Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 In this experiment you will identify a straight-chain carboxylic acid by titrating an aqueous solution of this acid with aqueous sodium hydroxide. 1 mole of the carboxylic acid reacts with 1 mole of sodium hydroxide. The carboxylic acid contains C, H and O atoms only and has no C=C bonds.

FA 1 is an aqueous solution of the carboxylic acid, containing 10.50 g dm^{-3} .

FA 2 is $0.110 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH.

FA 3 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Add approximately 8 drops of **FA 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FA 1** required cm^3 of **FA 2**. [1]

(c) Calculations

- (i) Calculate the amount, in mol, of sodium hydroxide present in the volume of **FA 2** calculated in (b).

amount of NaOH = ... mol [1]

- (ii) Use your answer to (c)(i) and the information on page 2 to calculate the relative formula mass of the carboxylic acid in **FA 1**.

M_r of carboxylic acid = ... [1]

- (iii) Identify the carboxylic acid in **FA 1**.
Draw its skeletal formula.

skeletal formula

name of acid [2]

- (d) A student carries out a similar titration to the titration you carried out in (a). The only difference is that a solution of aminoethanoic acid, $\text{NH}_2\text{CH}_2\text{CO}_2\text{H}$, containing 10.50 g dm^{-3} is used instead of the acid in **FA 1**.

- (i) Construct an equation for the reaction taking place in the student's titration.
Include state symbols.

..... [1]

- (ii) State whether the student's titre will be larger or smaller than your titre. Explain your answer.

The student's titre will be than mine.

explanation

.....

..... [1]

[Total: 14]

- 2 In this experiment you will identify a magnesium compound by thermal decomposition. When heated this compound decomposes to give magnesium oxide.

FA 4 is the magnesium compound.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**. Record the mass.
- Calculate the mass of **FA 4**. Record the mass.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, without the lid, for approximately 2 minutes.
- Heat strongly for a further 4 minutes.
- Place the lid on the crucible and leave it to cool for at least 5 minutes.

During the cooling period, you may wish to begin work on Question 3.

- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, without the lid, for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate the mass of residue obtained. Record the mass.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Calculate the amount, in mol, of magnesium oxide produced in your experiment.

amount of MgO = ... mol [1]

- (ii) 1 mole of **FA 4** decomposes on heating to produce 1 mole of MgO and 1 mole of gas **X**.

Calculate the relative formula mass, M_r , of **X**.

M_r of **X** = ... [1]

- (iii) **X** contains one or more oxygen atoms.

Suggest the identity of **X**.

X is [1]

- (iv) Deduce the name of **FA 4**.

FA 4 is [1]

- (c) A student suggests that this experiment will be more accurate if **FA 4** is heated throughout the experiment with a lid on the crucible.

State whether the student is correct. Explain your answer.

.....

 [1]

- (d) State the uncertainty in a single reading of your balance.

uncertainty = $\pm$ g

Calculate the maximum percentage error in the mass of residue that you obtained.
 Show your working.

maximum percentage error = ...%
 [1]

[Total: 11]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 (a) FA 5 is an ionic solid containing two ions. It contains one or more ions that contain nitrogen.

- (i) Carry out suitable tests to identify the anion. Reserve a small amount of **FA 5** for use in (a)(ii).

Record the tests you carry out and the observations you make, in a table, in the space below.

You **must** use a boiling tube if any liquid is heated.

anion in **FA 5** = ... [4]

- (ii) Heat a small spatula measure of **FA 5** in a hard-glass test-tube. When no further change occurs, allow the tube and its contents to cool completely.

Record **all** the observations you make and any subsequent conclusions.

.....

.....

.....

..... [2]

- (b) **FA 6** is a solution of a compound containing one cation and one anion, both of which are in the Qualitative analysis notes.

FA 7 is an aqueous mixture of two substances. **FA 7** contains one potassium-containing compound and one other substance. All substances are listed in the Qualitative analysis notes.

- (i) Carry out the following tests. Complete the table below.
Use a 1 cm depth of **FA 6** or **FA 7** in a test-tube for each test.

Table 3.1

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
Test 1 Add aqueous sodium hydroxide.		
Test 2 Add aqueous barium chloride or aqueous barium nitrate, then add dilute hydrochloric acid.		
Test 3 Add a few drops of aqueous starch, then add aqueous sodium thiosulfate.		
Test 4 Add a few drops of aqueous silver nitrate, then add a few drops of aqueous sodium hydroxide.		
Test 5 Add aqueous ammonia.		

[5]

- (ii) Give the formulae of the substances in **FA 6** and **FA 7**.

FA 6 is

FA 7 contains and [3]

- (iii) Give the ionic equation for **one** of the reactions taking place in **Test 1**.
Include state symbols.

..... [1]

[Total: 15]

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Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	no ppt. ammonia produced on warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																			
1	2													13	14	15	16	17	18

lanthanoids

actinoids

57	La lanthanum 138.9	58	Ce cerium 140.1	59	Pr praseodymium 140.9	60	Nd neodymium 144.4	61	Pm promethium	62	Sm samarium 150.4	63	Eu europium 152.0	64	Gd gadolinium 157.3	65	Tb terbium 158.9	66	Dy dysprosium 162.5	67	Ho holmium 164.9	68	Er erbium 167.3	69	Tm thulium 168.9	70	Yb ytterbium 173.1	71	Lu lutetium 175.0
89	Ac actinium	90	Th thorium 232.0	91	Pa protactinium 231.0	92	U uranium 238.0	93	Np neptunium	94	Pu plutonium	95	Am americium	96	Cm curium	97	Bk berkelium	98	Cf californium	99	Es einsteinium	100	Fm fermium	101	Md mendelevium	102	No nobelium	103	Lr lawrencium



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CHEMISTRY

9701/32

Paper 3 Advanced Practical Skills 2

May/June 2022

2 hours

You must answer on the question paper.

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INSTRUCTIONS

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Session	
Laboratory	

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages.

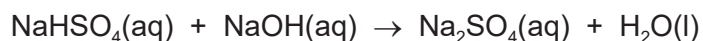
Quantitative analysis

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Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 A bottle containing the acid salt sodium hydrogen sulfate, NaHSO_4 , has been contaminated. You will determine the percentage purity by mass of the sodium hydrogen sulfate by titrating a solution of the acid salt against a known concentration of sodium hydroxide.



The impurity in the sodium hydrogen sulfate does not react with aqueous sodium hydroxide under the conditions of the titration.

FB 1 is $0.100 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH .

FB 2 is 12.53 g dm^{-3} impure sodium hydrogen sulfate.

FB 3 is thymol blue indicator.

(a) Method

- Fill a burette with **FB 1**.
- Pipette 25.0 cm^3 of **FB 2** into a conical flask.
- Add approximately 10 drops of **FB 3**.
- Perform a rough titration and record your burette readings in the space below. The end-point is shown by the appearance of a permanent blue colour.

The rough titre is cm^3 .

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record, in a suitable form below, all your burette readings and the volume of **FB 1** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm³ of **FB 2** required cm³ of **FB 1**. [1]

(c) Calculations

- (i) Give **all** your answers to (c)(ii), (c)(iii) and (c)(iv) to an appropriate number of significant figures. [1]
- (ii) Use your answer to (b) to calculate the amount, in mol, of sodium hydroxide, **FB 1**, titrated.

amount of NaOH = ... mol

Hence, deduce the amount, in mol, of sodium hydrogen sulfate present in 25.0 cm³ of **FB 2**.

amount of NaHSO₄ = ... mol [1]

- (iii) Use your final answer to (c)(ii) to calculate the mass of sodium hydrogen sulfate present in 1.00 dm³ of **FB 2**.

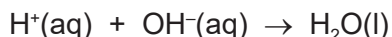
mass of NaHSO₄ = ... g [1]

- (iv) Use your answer to (c)(iii) and the information on page 2 to calculate the percentage purity by mass of the sodium hydrogen sulfate.

percentage purity = ... % [1]

[Total: 12]

2 In **Question 1** you carried out a neutralisation reaction involving sodium hydroxide.



In **Question 2** you are to determine the enthalpy of neutralisation, ΔH_{neut} , as shown by the equation above. You will use a solution of sodium hydroxide and the diprotic acid, sulfuric acid.

FB 4 is approximately 2 mol dm^{-3} sodium hydroxide, NaOH.

FB 5 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Place the cup in the 250 cm^3 beaker.
- Use the 25.0 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FB 4** into the cup.
- Place the thermometer in the solution. Record the temperature.
- Fill the clean burette with **FB 5**.
- Run 5.00 cm^3 of **FB 5** into the same cup.
- Stir the mixture and record the highest temperature observed.
- Repeat adding 5.00 cm^3 volumes of **FB 5** into the same cup until 45.00 cm^3 has been added. Record the highest temperature after each addition.

Results

Table 2.1

volume of FB 5 / cm^3	0.00	5.00	10.00	15.00	20.00
temperature / $^{\circ}\text{C}$					

volume of FB 5 / cm^3	25.00	30.00	35.00	40.00	45.00
temperature / $^{\circ}\text{C}$					

[3]

- (b) (i)** Plot a graph of temperature (y -axis) against volume of acid added (x -axis) on the grid provided. Select a scale on the y -axis to include a temperature 2.0°C above the highest temperature you recorded.

Label any points you consider to be anomalous. Draw two lines of best fit, one for the rise in temperature and one for the temperature change after the maximum temperature has been reached.

Extrapolate the two lines so they intersect.

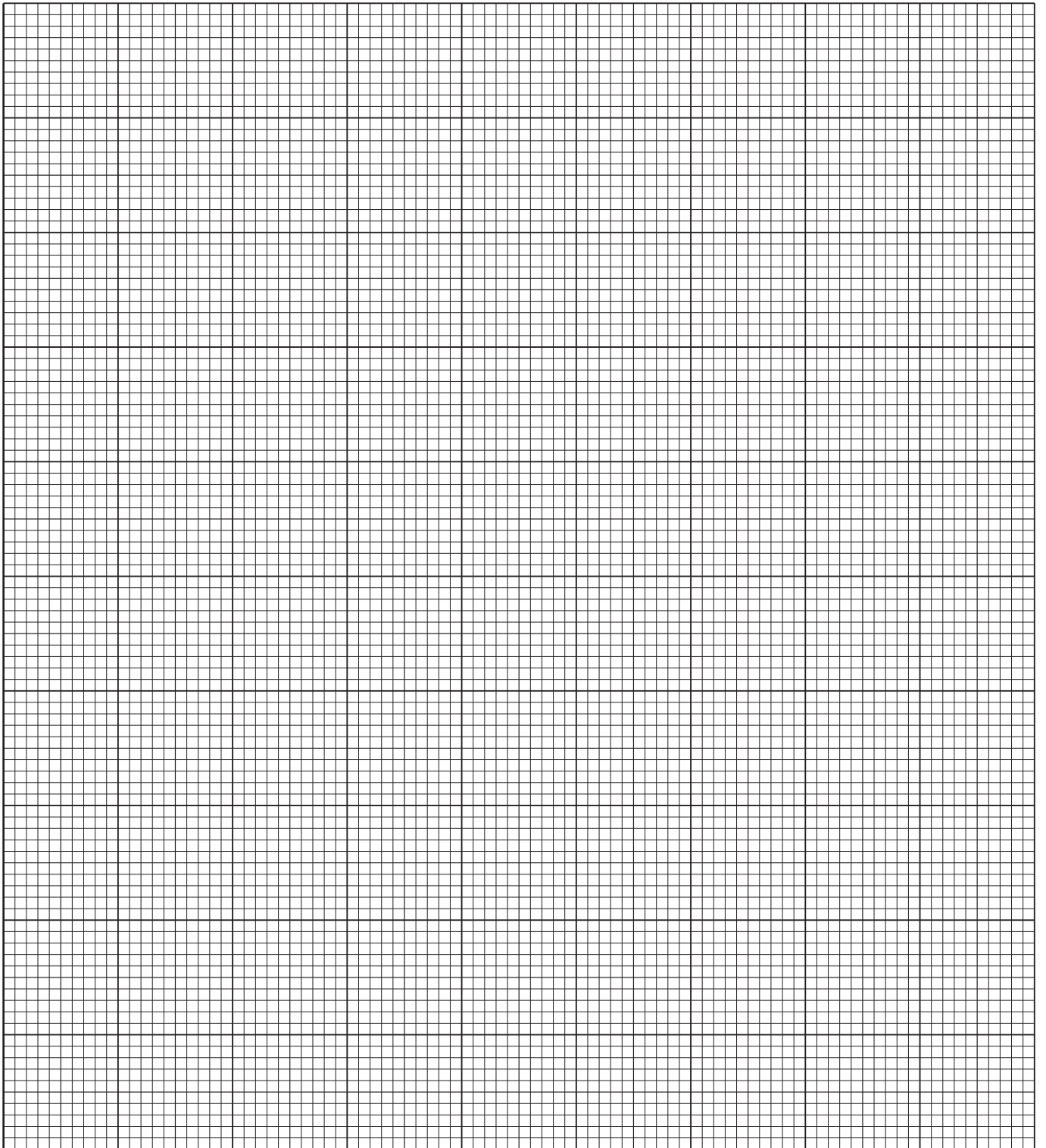
[4]

- (ii)** Use your graph to:

- determine the volume of sulfuric acid, **FB 5**, required to neutralise 25.0 cm^3 of sodium hydroxide, **FB 4**
- determine the maximum change in temperature, ΔT .

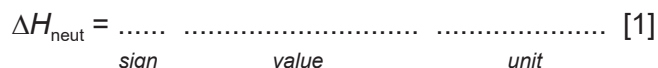
volume of $\text{H}_2\text{SO}_4 = \dots\dots\dots \text{cm}^3$

maximum $\Delta T = \dots\dots\dots ^{\circ}\text{C}$
[1]



(ii) Calculate the heat energy evolved in the neutralisation reaction in (a).
(Assume that 4.18 J are required to change the temperature of 1.0 cm³ of solution by 1.0 °C.)

(iii) Use your answers to (c)(i) and (c)(ii) to calculate the enthalpy of neutralisation, ΔH_{neut} , for the reaction given in (a).



- Calculate the percentage error in your answer to **(c)(iii)** compared with the theoretical value.

percentage error = ... % [1]

- (ii) Without changing the apparatus, suggest **one** improvement that could be made to the method in (a).
Explain your answer.

improvement

explanation

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- (e) (i) Use your graph and the information on page 4 to calculate the concentration, in mol dm^{-3} , of sodium hydroxide in **FB 4**.

concentration of NaOH = ... mol dm^{-3} [1]

- (ii) A student repeats **Question 1** with a new solution of **FB 1**.

The student decides to dilute **FB 4** by a factor of 20 to make the new **FB 1** solution.

The student incorrectly assumes the concentration of the new **FB 1** solution is $0.100 \text{ mol dm}^{-3}$.

Calculate the **actual** concentration of NaOH in the new **FB 1** solution.

(If you were unable to answer (e)(i) then assume the concentration of sodium hydroxide in **FB 4** was 1.93 mol dm^{-3} . This is not the correct value.)

concentration of NaOH in the new **FB 1** solution = ... mol dm^{-3}

Predict the effect that using the new **FB 1** solution has on the value for the percentage purity of the sodium hydrogen sulfate you calculated in **1(c)(iv)**.

The percentage purity of NaHSO_4 would be larger than calculated.	
The percentage purity of NaHSO_4 would be the same as calculated.	
The percentage purity of NaHSO_4 would be smaller than calculated.	

Tick the appropriate box and explain your answer.

.....

 [2]

[Total: 16]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

- 3 (a) FB 6** is the solid impurity found in the bottle of solid used to prepare **FB 2**. It is a compound of a Group 1 metal and does **not** contain sulfur. The anion in **FB 6** is listed in the Qualitative analysis notes.

Select a reagent, or reagents, and carry out **one** test on **FB 6** to collect more information about the anion present.

reagent or reagents

apparatus and conditions

.....

observations

.....

From your observations give the formula of the anion present.

If you are unable to identify the anion positively from your test and observations, then write 'unknown'.

formula of anion

[4]

- (b) (i) **FB 7** and **FB 8** are solutions containing a total of three cations. All of the cations are listed in the Qualitative analysis notes.

Carry out the following tests and record your observations. Use a fresh 1 cm depth of solution in a test-tube for each test.

Table 3.1

<i>test</i>	<i>observations</i>	
	FB 7	FB 8
Test 1 Add a few drops of acidified aqueous potassium manganate(VII).		
Test 2 Add aqueous ammonia.		
Test 3 Add aqueous sodium hydroxide, then		
decant the mixture into a boiling tube and warm gently.		

[4]

- (ii) Using your observations in (b)(i), identify the cations present in **FB 7** and **FB 8**. Write the formula of each cation identified. If the tests do not allow you to positively identify the cations, write 'unknown'.

cation or cations in **FB 7**

cation or cations in **FB 8**

[2]

- (iii) Construct the ionic equation for **one** reaction observed on addition of aqueous ammonia in **Test 2**. Include state symbols.

..... [1]

- (iv) Deduce the type of reaction which occurs when acidified aqueous potassium manganate(VII) is added to **FB 7** in **Test 1** in (b)(i).

..... [1]

[Total: 12]

Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	no ppt. ammonia produced on warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																					
1	2											1		13	14	15	16	17	18		
												1 H hydrogen 1.0								2 He helium 4.0	
												Key atomic number atomic symbol name relative atomic mass									
3 Li lithium 6.9	4 Be beryllium 9.0																				
11 Na sodium 23.0	12 Mg magnesium 24.3																				
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8				
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3				
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —			
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —			

lanthanoids

actinoids

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La lanthanum 138.9	Ce cerium 140.1	Pr praseodymium 140.9	Nd neodymium 144.4	Pm promethium —	Sm samarium 150.4	Eu europium 152.0	Gd gadolinium 157.3	Tb terbium 158.9	Dy dysprosium 162.5	Ho holmium 164.9	Er erbium 167.3	Tm thulium 168.9	Yb ytterbium 173.1	Lu lutetium 175.0
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac actinium —	Th thorium 232.0	Pa protactinium 231.0	U uranium 238.0	Np neptunium —	Pu plutonium —	Am americium —	Cm curium —	Bk berkelium —	Cf californium —	Es einsteinium —	Fm fermium —	Md mendelevium —	No nobelium —	Lr lawrencium —



Cambridge International AS & A Level

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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

May/June 2022

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has **12** pages. Any blank pages are indicated.



Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 Acids donate protons, H^+ , in aqueous solution. The number of moles of H^+ donated per mole of acid is the **proticity** of the acid. In this experiment, you will carry out a titration to determine the proticity of phosphoric acid, H_3PO_4 , when it reacts with sodium hydroxide, NaOH .

FA 1 is aqueous phosphoric acid, containing $6.86 \text{ g dm}^{-3} \text{ H}_3\text{PO}_4$.

FA 2 is $0.150 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH .

FA 3 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Add a few drops of **FA 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
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VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtained the mean value.

25.0 cm^3 of **FA 1** required cm^3 of **FA 2**. [1]

(c) Calculations

- (i) Calculate the amount, in mol, of sodium hydroxide present in the volume of **FA 2** calculated in (b).

amount of NaOH = ... mol [1]

- (ii) Use the information on page 2 to calculate the amount, in mol, of phosphoric acid present in 25.0 cm³ of **FA 1**.

amount of H₃PO₄ = ... mol [1]

- (iii) Deduce whether phosphoric acid behaves as a monoprotic, diprotic or triprotic acid in this titration. Explain your reasoning.

H₃PO₄ is a protic acid.

explanation

.....
 [1]

- (iv) Give the equation for this reaction of phosphoric acid, H₃PO₄, with sodium hydroxide.

..... [1]

- (d) (i) A student uses a pipette that is labelled 25.0 ± 0.06 cm³ to measure **FA 1**.

Calculate the maximum percentage error in the volume of **FA 1**. Show your working.

maximum percentage error = ...% [1]

- (ii) The student suggests it would be more accurate to measure the volume of **FA 1** with a burette instead of the pipette.

State whether you agree with the student. Explain your answer.

.....
 [1]

[Total: 14]

- 2 In this experiment you will identify the metal, **M**, in a metal carbonate, **MCO₃**, by thermal decomposition.



FA 4 is the metal carbonate, **MCO₃**.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** used.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately 1 minute.
- Heat strongly, with the lid off, for a further 4 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.

During the cooling period, you may wish to begin work on Question 3.

- When the crucible has cooled, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, with the lid off, for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the total loss of mass and the mass of residue obtained.
- This residue is **FA 5**.

Keep FA 5 for use in 2(d).

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide given off in your experiment.

amount of CO₂ = ... mol [1]

- (ii) Calculate the relative formula mass, M_r , of MCO_3 .

M_r of MCO_3 = ... [1]

- (iii) From your results, deduce the identity of **M**.
Show your reasoning.

M is = ... [1]

- (c) A student carries out the same procedure, using the same mass of solid. However, the student uses the basic carbonate, $\text{MCO}_3 \cdot \text{M}(\text{OH})_2$, instead of the pure carbonate, MCO_3 .

When the metal hydroxide part of the basic carbonate decomposes, metal oxide and steam are produced. The metal carbonate part decomposes in the usual way.

State how the loss of mass from the student's solid compares with the loss of mass you obtained when you carried out your experiment. Explain your reasoning.

.....
..... [2]

- (d) Use a spatula to transfer a small quantity of your cold residue, **FA 5**, into a test-tube. Add about a 1 cm depth of dilute hydrochloric acid to the **FA 5** in the test-tube.

Record what you observe.

.....
.....

State whether or not the thermal decomposition of MCO_3 is complete.

Justify your answer based on your observations.

.....
.....
..... [2]

[Total: 12]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 (a) Solutions **FA 6** and **FA 7** each contain one cation and one anion. All the ions are listed in the Qualitative analysis notes.

- (i) Carry out the following tests, using a 1 cm depth of **FA 6** or **FA 7** in a test-tube for each test. Complete the table below.

Table 3.1

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
Test 1 Add an equal volume of aqueous potassium iodide, then		
add excess aqueous sodium thiosulfate.		
Test 2 Add a small spatula measure of zinc powder. Leave the mixture to stand.		
Test 3 Add a few drops of aqueous silver nitrate.		
Test 4 Add aqueous sodium hydroxide.		

- (ii) Construct an ionic equation for **one** of the reactions taking place in **Test 2**. Include state symbols.

..... [1]

- (b) **FA 8** contains one anion and one cation. One of these ions contains nitrogen. Both ions are listed in the Qualitative analysis notes.

- (i) Transfer a small spatula measure of **FA 8** into a hard-glass test-tube. Heat the test-tube gently at the start, then strongly until no further change occurs. Leave the test-tube to cool.

Record all your observations.

.....

 [2]

- (ii) Carry out further tests to identify **each** ion in **FA 8**.

Record, in a table in the space below, the reagents, conditions and observations for the tests that positively identify **each** ion.
 You may wish to use the following page for rough working.

Deduce the chemical formula of **FA 8**.

You **must** use a boiling tube if any liquid is heated.

The formula of **FA 8** is [6]

[Total: 14]

Use this page for any rough working.

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Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	no ppt. ammonia produced on warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																						
1	2													13	14	15	16	17	18			
														1 H hydrogen 1.0								2 He helium 4.0
																				Key		
																				atomic number atomic symbol name relative atomic mass		
3 Li lithium 6.9	4 Be beryllium 9.0													5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2			
11 Na sodium 23.0	12 Mg magnesium 24.3													13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9			
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8					
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3					
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —				
87 Fr francium —	88 Ra radium —	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —				

lanthanoids

actinoids

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
lanthanum	cerium	praseodymium	neodymium	promethium	samarium	europlum	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
138.9	140.1	140.9	144.4	—	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—



CANDIDATE
NAME

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CANDIDATE
NUMBER

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9701/34

May/June 2022

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
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- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **16** pages. Any blank pages are indicated.



Quantitative analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 Calcium carbonate reacts with hydrochloric acid to release carbon dioxide.



The concentration of the hydrochloric acid can be determined by reacting it with calcium carbonate and measuring the volume of carbon dioxide formed.

FB 1 is hydrochloric acid, HCl.

FB 2 is calcium carbonate, CaCO₃.

(a) Method

- Fill the tub with tap water to a depth of approximately 5 cm.
- Fill the 250 cm³ measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Using the 50 cm³ measuring cylinder, transfer 50 cm³ of **FB 1** into the flask. Check that the bung fits tightly into the neck of the flask, clamp the flask and place the end of the delivery tube into the inverted 250 cm³ measuring cylinder.
- Remove the bung from the neck of the flask. Tip all the **FB 2**, from the container, into the acid in the flask and replace the bung immediately. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp. Leave for several minutes, swirling the flask occasionally.

You may wish to start Question 3 while the gas is being produced.

- When the reaction stops producing gas, record the final volume of gas in the measuring cylinder.

Keep the flask and contents for use in 1(c)(i).

volume of gas = ... cm³ [2]

(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder.
(Assume that 1 mol of gas occupies 24.0 dm^3 under these conditions.)

amount of $\text{CO}_2 = \dots\dots\dots \text{ mol}$ [1]

- (ii) Use your answer to **(b)(i)** and the equation on page 2 to calculate the concentration, in mol dm^{-3} , of hydrochloric acid in **FB 1**. Show your working.

concentration of $\text{HCl} = \dots\dots\dots \text{ mol dm}^{-3}$
[2]

- (c) (i)** A student thinks that the mass of **FB 2** should be measured.

Explain, by observing the contents of the flask, why this is not necessary.

.....
.....
..... [2]

- (ii)** In this experiment some carbon dioxide is lost before the bung is replaced.

Suggest a change that could be made to minimise the loss of gas. Explain how this change minimises the loss of gas.

.....
.....
..... [1]

[Total: 8]

- 2 In this experiment you will use a thermometric method to determine the concentration of a sample of alkali. You will mix varying volumes of acid with a fixed volume of the alkali and measure the temperature rises that occur.

You will use your experimental data to calculate the enthalpy change for the neutralisation of the acid with alkali.

FB 3 is aqueous sodium hydroxide, NaOH.

FB 4 is 2.20 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Use the thermometer to measure the initial temperature of **FB 3**.

initial temperature of **FB 3** = ... °C

- Fill a burette with distilled water.
- Fill the other burette with **FB 4**. Label this burette **FB 4**.
- For **Experiment 1**, use the 10 cm^3 pipette to transfer 10.0 cm^3 of **FB 3** into the cup.
- Add 9.00 cm^3 of distilled water from the burette into the same cup.
- Add 1.00 cm^3 of **FB 4** from the other burette into the same cup.
- Stir the mixture and use the thermometer to measure the maximum temperature obtained.
- Record the maximum temperature in the table.
- Empty and shake dry the cup ready for use in **Experiment 2**.
- Repeat the method using 10.0 cm^3 of **FB 3** for each experiment and the volumes of water and **FB 4** shown in the table. In each case, measure and record the maximum temperature.

Table 2.1

experiment	volume water / cm^3	volume FB 4 / cm^3	maximum temperature / °C
1	9.00	1.00	
2	7.00	3.00	
3	5.00	5.00	
4	3.00	7.00	
5	1.00	9.00	
6			
7			

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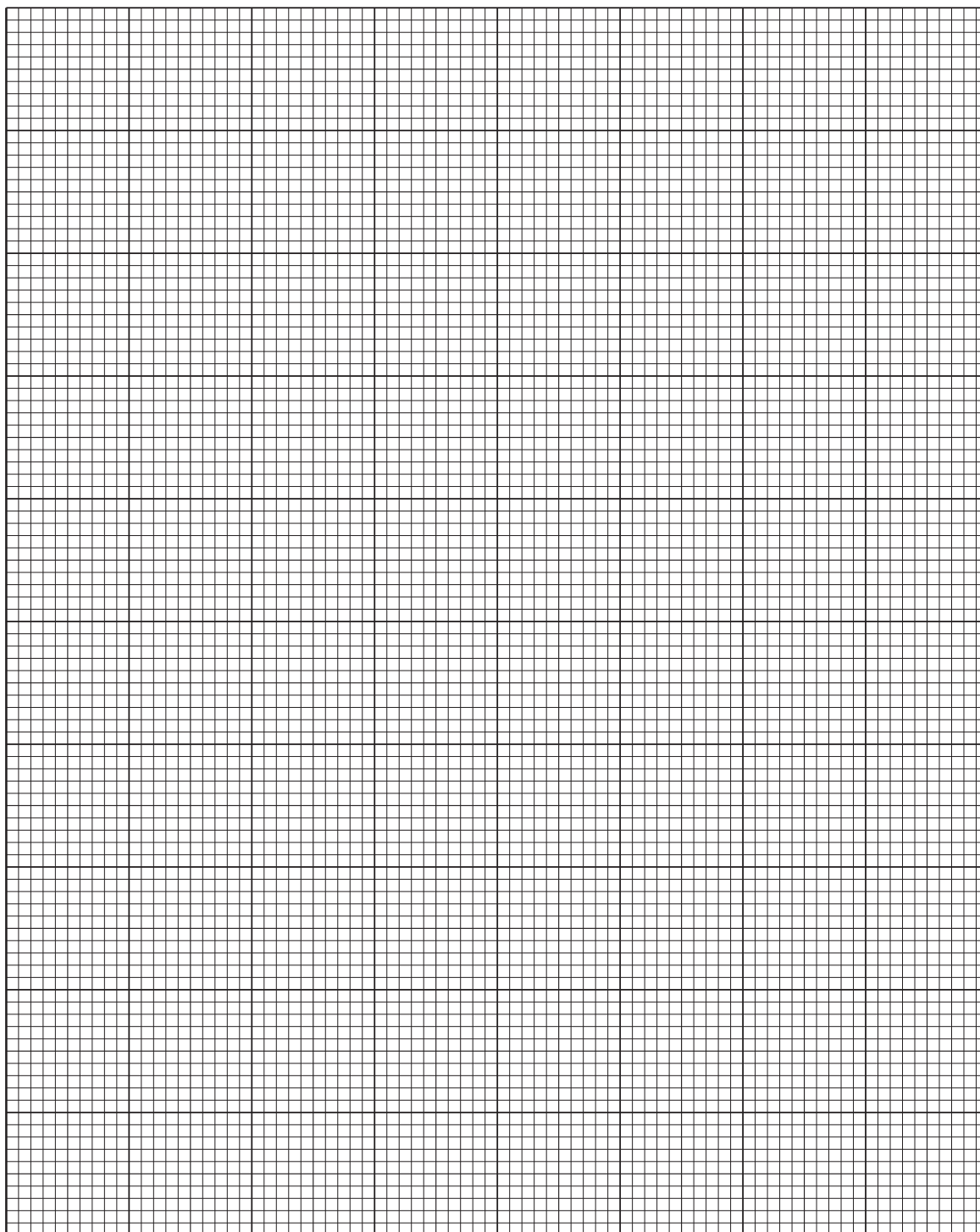
Carry out **two** further experiments which will enable you to determine more precisely the volume of **FB 4** that gives the highest maximum temperature.

Record your measurements for these **two** experiments in the table.

[5]

- (b) Plot a graph of the maximum temperature reached (y-axis) and the volume of **FB 4** used (x-axis).

The scale on the y-axis should include a temperature 2°C above the highest maximum temperature reached. Circle any points you consider to be anomalous.



I	
II	
III	
IV	

Draw two straight lines of best fit on your graph. One line should show where the maximum temperature recorded was increasing. The other line should be after the highest maximum temperature. Extrapolate both lines so that they intersect.

Use your graph to determine the volume of **FB 4** that reacts with 10.00 cm³ of **FB 3**.

volume of **FB 4** = ... cm³ [4]

- (c) (i)** Give your answers to **(c)(ii)**, **(c)(iii)**, **(c)(iv)** and **(c)(v)** to an appropriate number of significant figures. [1]

- (ii) Calculate the amount, in mol, of hydrochloric acid in the volume of **FB 4** in (b).
If you were unable to determine an answer to (b) use 4.10 cm^3 as the volume of **FB 4**.

amount of HCl = ... mol [1]

- (iii) Use your answer to (c)(ii) and the information on page 4 to calculate the concentration, in mol dm^{-3} , of sodium hydroxide in **FB 3**.

concentration of NaOH = ... mol dm⁻³ [1]

- (iv) Calculate the energy released when the volume of **FB 4** in (b) is neutralised by sodium hydroxide. Show your working.
(Assume that 4.18 J of energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.)

energy released = ... J [2]

- (v) Use your answers to (c)(ii) and (c)(iv) to calculate the enthalpy change of neutralisation, in kJ mol^{-1} , for 1.0 mol of hydrochloric acid.

enthalpy change = ... kJ mol⁻¹
sign value [1]

- (d) (i) The theoretical value of the enthalpy change of neutralisation is $-57.6 \text{ kJ mol}^{-1}$.

Calculate the percentage error in your value of the enthalpy change from (c)(v).
Show your working.

(Assume that the conditions under which you carried out your experiment in (a) are identical to the conditions used to determine the theoretical value.)

percentage error = ... % [1]

- (ii) Suggest **one** modification to the procedure used in (a) that would give a more accurate value for the enthalpy change of neutralisation.

Do **not** suggest any modifications to apparatus in your answer.

.....
.....
.....
..... [1]

[Total: 17]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

- 3** Half fill the 250cm³ beaker with water, heat until the water is nearly boiling and then turn off the Bunsen burner. This is your hot water bath for use in **(a)(i)**.

- (a)** You are provided with aqueous solutions **FB 5**, **FB 6**, **FB 7** and **FB 8**. The solutions are known to be hydrochloric acid, hydrogen peroxide, methanoic acid and sulfuric acid. All the solutions have the same concentration.

Note: the order of **FB 5** to **FB 8** does **not** correspond to the order of identities given above.

- (i)** Carry out the following tests using a 2cm depth of each reagent in a test-tube. Record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>			
	FB 5	FB 6	FB 7	FB 8
Test 1 Add a piece of magnesium.				
Test 2 Add a few drops of acidified aqueous potassium manganate(VII). Place the test-tube in the hot water bath.				

[5]

- (ii) Use your observations to complete the sentences. Explain your answer.

FB 7 is

FB 8 is

explanation

..... [2]

- (iii) Carry out **one** additional test that allows you to distinguish between **FB 5** and **FB 6**.

Record your test and the result you obtained.

FB 5 is

FB 6 is

[2]

- (iv) Write an **ionic** equation for the reaction of magnesium with **FB 5**. Include state symbols.

..... [1]

- (v) Describe the observations that you would expect to see if the tests in **(a)(i)** were repeated using aqueous ethanoic acid.

observation with magnesium

.....

observation with acidified aqueous potassium manganate(VII)

.....

[2]

- (b) **FB 9** is an aqueous solution containing one cation from those listed in the Qualitative analysis notes.

Carry out tests that would identify the cation present in **FB 9**. Record your tests, observations and the identity of the cation.

The cation is

[3]

[Total: 15]

Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	no ppt. ammonia produced on warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																			
1	2											13	14	15	16	17	18		
3 Li lithium 6.9	4 Be beryllium 9.0	Key atomic number atomic symbol name relative atomic mass										1 H hydrogen 1.0							
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2		
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8		
																		13 Al aluminium 27.0	14 Si silicon 28.1
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3		
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —		
87 Fr francium —	88 Ra radium —	89–103 actinoids	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —		

lanthanoids

57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium —	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
89 Ac actinium —	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium —	94 Pu plutonium —	95 Am americium —	96 Cm curium —	97 Bk berkelium —	98 Cf californium —	99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —

actinoids



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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

May/June 2022

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has **12** pages.



Quantitative analysis

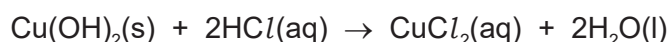
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show the precision of the apparatus you used in the data you record.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 Basic copper(II) carbonate contains both copper(II) carbonate, CuCO_3 , and copper(II) hydroxide, $\text{Cu}(\text{OH})_2$. The ratio of these two components can be different in samples from different sources. This means that the formula of basic copper(II) carbonate can be written as $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$.

Both the carbonate and the hydroxide react with acids.



You will determine the value of **x** in a sample of basic copper(II) carbonate by reacting it with excess acid and measuring the mass of carbon dioxide given off.

FA 1 is basic copper(II) carbonate, $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$.

FA 2 is 2.0 mol dm^{-3} hydrochloric acid, HCl .

(a) Method

- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 2** into a conical flask.
- Weigh the flask with the acid. Record the mass.
- Weigh the container with **FA 1**. Record the mass.
- Carefully tip all of **FA 1** into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** added to the flask.
- Calculate and record the theoretical initial mass of flask + acid + **FA 1**.
- Swirl the flask occasionally. Weigh the flask and contents after approximately 5 minutes. Record the mass.

During this step you may wish to continue with Question 2 or Question 3.

- Calculate and record the mass of carbon dioxide given off during the experiment.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide given off in the reaction.

amount of CO_2 = ... mol [1]

- (ii) Calculate the amount, in mol, of copper(II) carbonate in the sample of **FA 1** that you added to the flask.

amount of CuCO_3 = ... mol

Hence calculate the mass of copper(II) carbonate in the sample of **FA 1** that you added to the flask.

mass of CuCO_3 = ... g
[1]

- (iii) Calculate the mass of copper(II) hydroxide in the sample of **FA 1** that you added to the flask.

mass of Cu(OH)_2 = ... g [1]

- (iv) Calculate the amount, in mol, of copper(II) hydroxide in the sample of **FA 1** that you added to the flask.

amount of Cu(OH)_2 = ... mol

Hence calculate the value of **x** in the formula of basic copper(II) carbonate, $\text{CuCO}_3 \cdot x\text{Cu(OH)}_2$.

x = ...
[1]

- (c) In this determination you assume that hydrochloric acid is in excess.

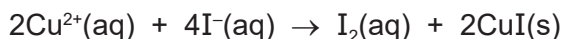
Show, by calculation, that this assumption is correct.

[2]

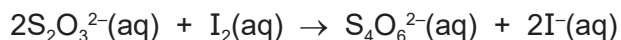
[Total: 10]

- 2 In **Question 1** you found the value of **x** in the formula of basic copper(II) carbonate, $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$. You will now use another method to find the value of **x**.

Copper(II) ions oxidise iodide ions to produce iodine.



The amount of iodine produced can be found by titration with aqueous thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$.



FA 3 contains $\text{Cu}^{2+}(\text{aq})$. It was made by reacting 10.40 g of $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$ with excess dilute sulfuric acid and making the solution up to 1.00 dm^3 with distilled water.

FA 4 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 5 is aqueous potassium iodide, KI.

FA 6 is starch indicator.

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Rinse the 25 cm^3 measuring cylinder with approximately 5 cm^3 of **FA 5**. Discard the solution used for rinsing.
- Use the 25 cm^3 measuring cylinder to add 15 cm^3 of **FA 5**, an excess of KI, to the conical flask. The solution will turn brown because iodine is formed.
- Add **FA 4** from the burette until the mixture changes to pale brown.
- Add approximately 10 drops of **FA 6**. The mixture will turn blue-black.
- Continue adding **FA 4** from the burette until the blue-black colour disappears to leave an off-white solid. This is the end-point of the titration.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record in a suitable form below, all your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to be used in your calculations. Show clearly how you have obtained the mean value.

25.0 cm³ of **FA 3** required cm³ of **FA 4**. [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to the appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of thiosulfate ions present in the volume of **FA 4** you have calculated in (b).

amount of S₂O₃²⁻ = ... mol [1]

- (iii) Use your answer to (c)(ii), and the equations for the reactions involved, to calculate the amount, in mol, of copper(II) ions present in 25.0 cm³ of **FA 3**.

amount of Cu²⁺ in 25.0 cm³ = ... mol

Hence deduce the amount, in mol, of copper(II) ions present in 1.00 dm³ of **FA 3**.

amount of Cu²⁺ in 1.00 dm³ = ... mol [1]

- (iv) Use your answer to (c)(iii) to calculate the mass of copper(II) ions in 1.00 dm³ of **FA 3**.

mass of Cu²⁺ in 1.00 dm³ = ... g [1]

- (v) The formula of basic copper(II) carbonate is $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$.

Write an expression, including x , for the mass of Cu^{2+} ions in one mole of $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$.

mass of Cu^{2+} ions in one mole of $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2 = \dots\dots\dots \text{ g [1]}$

- (vi) The formula of basic copper(II) carbonate is $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$.

Write an expression, including x , for the mass of one mole of $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$.

mass of one mole of $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2 = \dots\dots\dots \text{ g [1]}$

- (vii) The expression below links the masses of copper(II) ions in **FA 3** and in one mole.

$$\frac{\text{mass of Cu}^{2+} \text{ present in sample of FA 3}}{\text{mass of CuCO}_3 \cdot x\text{Cu}(\text{OH})_2 \text{ used}} = \frac{\text{mass of Cu}^{2+} \text{ in one mole of CuCO}_3 \cdot x\text{Cu}(\text{OH})_2}{\text{mass of one mole of CuCO}_3 \cdot x\text{Cu}(\text{OH})_2}$$

Using this expression, show how you could determine the value of x in the formula of basic copper(II) carbonate, $\text{CuCO}_3 \cdot x\text{Cu}(\text{OH})_2$.

[3]

[Total: 17]

Qualitative analysis

For each test you should record all your observations in the spaces provided.

Examples of observations include:

- colour changes seen
- the formation of any precipitate and its solubility (where appropriate) in an excess of the reagent added
- the formation of any gas and its identification (where appropriate) by a suitable test.

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

If any solution is warmed, a boiling tube must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 (a) FA 7 is a sample of basic copper(II) carbonate.

Place a small spatula measure of **FA 7** into a hard-glass test-tube and heat the tube, gently at first and then more strongly.

Record **all** your observations.

.....

.....

.....

..... [2]

(b) **FA 8** is an aqueous solution containing Cu^{2+} ions.

- (i) Carry out the following tests using a 1 cm depth of **FA 8** in a test-tube for each test. Record your observations.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add a 1 cm depth of aqueous EDTA.	
Test 2 Add concentrated hydrochloric acid (CARE, corrosive) dropwise until no further change is seen.	
Test 3 Add a small spatula measure of metal M . Leave the test-tube to stand.	

[2]

- (ii) Suggest a possible ionic equation for the reaction between **M** and **FA 8** in **Test 3**. Include state symbols.

..... [1]

(c) Carry out tests to identify **M**. Use only a small spatula measure of **M**. Do **not** use concentrated hydrochloric acid in your tests.

- (i) Record the tests you carry out and the observations you make, in a table, in the space below.

[3]

- (ii) From your observations in (c)(i), identify **M**.

M is [1]

(d) **FA 9** and **FA 10** are sodium compounds that contain either a halide or a carbonate.

Carry out tests to confirm the identity of **FA 9** and **FA 10**.

Record the tests you carry out, the observations you make and your conclusions in a table in the space below.

[4]

[Total: 13]

Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	no ppt. ammonia produced on warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																					
1	2													13	14	15	16	17	18		
														1 H hydrogen 1.0							