



Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--



CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

October/November 2023

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

Total

This document has **12** pages.

Quantitative analysis

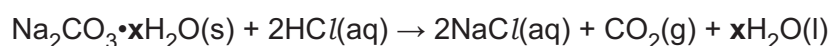
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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 You will determine the value of **x** in hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$. **x** is **not** an integer.

You will carry out two methods to determine the value of **x**. Each method involves sodium carbonate reacting with excess hydrochloric acid to release carbon dioxide.



(a) Experiment 1

You will measure the volume of carbon dioxide released when hydrated sodium carbonate reacts with excess hydrochloric acid.

FA 1 is $0.500 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FA 2 is hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

Method

- Weigh the container with **FA 2**. Record the mass.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder completely with water. Holding 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 cm^3 measuring cylinder, transfer 50.0 cm^3 of **FA 1** into the flask labelled **Z**. Check that the bung fits tightly into the neck of flask **Z**, clamp flask **Z** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip all the **FA 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. You may need to shake the flask quite vigorously until the gas formed starts to collect in the measuring cylinder.
- Return the flask to the clamp. Leave for several minutes, shaking the flask occasionally.
- Weigh the container with any residual **FA 2**. Record the mass.
- Calculate the mass of **FA 2** added to the flask. Record the mass.
- When no more gas is collected, measure the final volume of gas in the measuring cylinder. Record the volume.

Results

I	
II	
III	

[3]

(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder at room conditions.

amount of CO_2 = ... mol

Hence deduce the amount, in mol, of sodium carbonate present in the **FA 2** you added in your experiment.

amount of Na_2CO_3 = ... mol
[1]

- (ii) Use your answer to (b)(i) and the mass of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, you used in **Experiment 1** to calculate the relative formula mass, M_r , of the $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

M_r of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ = ... [1]

- (iii) Use your answer to (b)(ii) to calculate the value of x in the $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.
Show your working.

x = ... [2]

(c) A student suggests that it would be better to use hot water in the tub.

(i) State whether using hot water would be an improvement. Explain your answer.

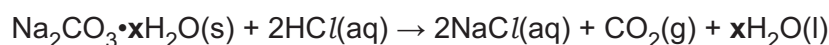
.....
 [1]

(ii) State the effect, if any, that using hot water would have on the value of **x** calculated.

.....
 [1]

(d) **Experiment 2**

You will carry out a titration to measure the volume of hydrochloric acid that neutralises an aqueous solution of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.



FA 3 is $0.100 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FA 4 is an aqueous solution containing 14.30 g dm^{-3} of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

FA 5 is bromophenol blue indicator.

Method

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add a few drops of **FA 5**.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (e) 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 **FA 4** required cm³ of **FA 3**. [1]

(f) Calculations

- (i) Give your answers to **(f)(ii)**, **(f)(iii)** and **(f)(iv)** to an appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of hydrochloric acid present in the volume of **FA 3** you calculated in **(e)**.

amount of HCl = ... mol [1]

- (iii) Use the equation for the neutralisation to deduce the amount, in mol, of sodium carbonate present in 25.0 cm³ of Na₂CO₃·xH₂O.

amount of Na₂CO₃ = ... mol

Hence calculate the amount, in mol, of sodium carbonate in 1.00 dm³ of Na₂CO₃·xH₂O.

amount of Na₂CO₃ in 1.00 dm³ = ... mol [1]

- (iv) Calculate the value of **x** in the sample of Na₂CO₃·xH₂O.
Show your working.

x = ... [1]

- (g) The aqueous solution of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, **FA 4**, was prepared by weighing and dissolving the solid to make 1.00 dm^3 of solution.

Mass of container + $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$	= 32.509 g
Mass of empty container	= 18.209 g
Mass of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$	= 14.300 g

- (i) State the maximum uncertainty in a single balance reading for the balance used.

maximum uncertainty = $\pm$ g

Calculate the maximum percentage uncertainty in this mass of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.
Show your working.

maximum percentage uncertainty = $\pm$ %
[1]

- (ii) Using the method in **Experiment 2** a student calculated the relative formula mass, M_r , of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ to be 242.2. Assume that the uncertainty in the mass of **FA 4** is the only source of error in the experiment.

Calculate the maximum value for the relative formula mass of **FA 4**.

maximum value for the relative formula mass of **FA 4** = ... [1]

[Total: 23]

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.

- 2 (a) FA 6, FA 7 and FA 8** are salts each of which contains nitrogen. Each of the nitrogen-containing ions is different and all are shown in the Qualitative analysis notes.

- (i) List the nitrogen-containing ions for which you will test.

..... and and

Select reagents to positively identify the nitrogen-containing ions in each salt. Record your tests and the results with each salt in a suitable table in the space below.

[8]

- (ii) Use your observations in (a)(i) to determine the formulae of the nitrogen-containing ions present in **FA 6**, **FA 7** and **FA 8**.

FA 6 **FA 7** **FA 8** [1]

- (b) **FA 9** and **FA 10** contain the same element. You will identify this element by carrying out tests.

(i) **Test 1**

Heat a small spatula measure of **FA 9** in a hard-glass test-tube. Heat until the reaction stops.

After heating, leave the tube to cool and keep it for Test 2. You may wish to start (b)(ii) while you wait.

Record your observations.

.....

Name **one** product of the reaction.

product

Test 2

To the cooled solid product of **Test 1**, add a 2–3 cm depth of distilled water. Shake the test-tube and then leave the contents to settle.

Record your observations.

.....

[3]

- (ii) To a **very small** spatula measure of **FA 9** in a test-tube, add about a 2 cm depth of dilute sulfuric acid and about a 2 cm depth of distilled water. Shake to dissolve the **FA 9** and produce **FA 9(aq)**.

You will use **FA 9(aq)** in **Test 3** and **Test 4**.

Test 3

To a 1 cm depth of aqueous iron(II) sulfate in a test-tube, add a few drops of **FA 9(aq)**.

Record your observations.

.....

Test 4

To a 1 cm depth of aqueous potassium iodide in a test-tube, add a few drops of **FA 9**(aq).

Record your observations.

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

- (iii) To a small spatula measure of **FA 10** in a test-tube, add distilled water to dissolve the **FA 10**. This solution is **FA 10**(aq).

To a 1 cm depth of **FA 10**(aq), add aqueous sodium hydroxide.

Record your observations.

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

- (iv) Identify the element that is present in **FA 9** and **FA 10**.

element [1]

[Total: 17]

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																			
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 rhenium 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 coppernium —																			
113 Nh nihonium —																			
114 Fl flerovium —																			
115 Mc moscovium —																			
116 Lv livermorium —																			
117 Ts tennessine —																			
118 Og oganesson —																			



Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

October/November 2023

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 You will carry out a titration to determine the concentration of a solution of potassium manganate(VII), KMnO_4 . Potassium manganate(VII) reacts with excess acidified potassium iodide to produce iodine. This iodine is titrated with aqueous sodium thiosulfate.

FA 1 is aqueous potassium manganate(VII), KMnO_4 .

FA 2 is $0.500 \text{ mol dm}^{-3}$ potassium iodide, KI .

FA 3 is $0.120 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 4 is dilute sulfuric acid, H_2SO_4 .

FA 5 is starch indicator.

(a) Method

Titration

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10.0 cm^3 of **FA 2** to the conical flask.
- Use the 50 cm^3 measuring cylinder to add 15.0 cm^3 of **FA 4** to the conical flask.
- Perform a rough titration by adding **FA 3** from the burette to the conical flask until the solution is yellow.
- Then add several drops of **FA 5**. Continue the titration until the mixture in the flask becomes colourless. This is the end-point.
- Record the initial and final 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 3** added in each accurate titration.

Keep FA 2 and FA 5 for use in Question 3(b).

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 obtained the mean value.

The iodine produced by **FA 1** required cm^3 of **FA 3**. [1]

(c) **Calculations**

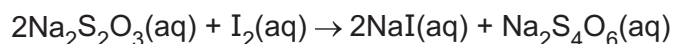
- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to the appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of sodium thiosulfate in the volume of **FA 3** calculated in (b).

amount of $\text{Na}_2\text{S}_2\text{O}_3$ = ... mol [1]

- (iii) The reaction by which iodine is produced is shown.



During the titration, sodium thiosulfate reacts with the iodine produced.



Calculate the concentration of potassium manganate(VII), in mol dm^{-3} , in **FA 1**.

concentration of KMnO_4 = ... mol dm^{-3} [2]

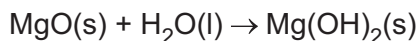
- (iv) A laboratory technician purchased a bottle containing 50.00g of potassium manganate(VII), KMnO_4 , for this practical examination. Using your answer to (c)(iii), calculate the maximum volume of **FA 1**, in dm^3 , that the technician can prepare using the contents of this bottle.

volume of **FA 1** = ... dm^3 [1]

- (d) A student suggested that the accuracy of the experiment would be increased by using a 10 cm^3 pipette to measure **FA 2**.
State whether the student is correct. Explain your answer.

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

- 2 You will determine the enthalpy change for the reaction of magnesium oxide with water to form magnesium hydroxide.



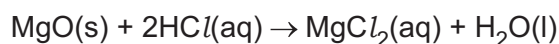
The procedure will involve two experiments, one with magnesium oxide and the other with magnesium hydroxide. In each case you will react the solid with hydrochloric acid.

FA 6 is magnesium oxide, MgO .

FA 7 is 2.0 mol dm^{-3} hydrochloric acid, HCl .

FA 8 is magnesium hydroxide, Mg(OH)_2 .

- (a) **Experiment 1** is the determination of the enthalpy change of reaction, ΔH_1 , of magnesium oxide with hydrochloric acid.



(i) **Method**

- Support a cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of **FA 7** into the cup.
- Measure and record the temperature of the solution in the cup.
- Weigh the container with **FA 6**. Record the mass.
- Tip all of **FA 6** into the cup containing **FA 7**. **FA 7** is in excess.
- Stir the mixture until the maximum temperature is obtained. Record the maximum temperature.
- Weigh the container with any residual **FA 6**. Record the mass.
- Calculate and record the mass of **FA 6** used.
- Calculate and record the temperature rise.

I	
II	
III	

[3]

- (ii) Calculate the energy released in your experiment.

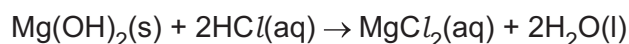
energy released = ... J [1]

- (iii) Calculate the enthalpy change of reaction, ΔH_1 , in kJ mol^{-1} of MgO(s) , for the reaction of magnesium oxide with hydrochloric acid.
Show your working.

$$\Delta H_1 = \begin{array}{cc} \text{.....} & \text{.....} \end{array} \text{ kJ mol}^{-1}$$

sign *value* [2]

- (b) **Experiment 2** is the determination of the enthalpy change of the reaction, ΔH_2 , of magnesium hydroxide with hydrochloric acid.



(i) **Method**

- Place the other cup in the beaker.
- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of **FA 7** into the cup.
- Measure and record the temperature of the solution in the cup.
- Weigh the container with magnesium hydroxide, **FA 8**. Record the mass.
- Tip all of **FA 8** into the cup containing **FA 7**. **FA 8** is in excess.
- Stir the mixture until the maximum temperature is obtained. Record the maximum temperature.
- Weigh the container with any residual **FA 8**. Record the mass.
- Calculate and record the mass of **FA 8** used.
- Calculate and record the temperature rise.

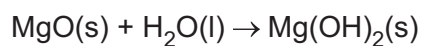
I	
II	
III	

[3]

- (ii) Calculate the enthalpy change of reaction, ΔH_2 , in kJ mol^{-1} of $\text{Mg(OH)}_2(\text{s})$, for the reaction of magnesium hydroxide with hydrochloric acid.
Show your working.

$$\Delta H_2 = \begin{array}{c} \text{.....} \\ \text{sign} \end{array} \begin{array}{c} \text{.....} \\ \text{value} \end{array} \text{ kJ mol}^{-1} \quad [2]$$

- (c) Use your answers to (a)(iii) and (b)(ii) to calculate the enthalpy change, ΔH_r , in kJ mol^{-1} , for the reaction between magnesium oxide and water. The equation for the reaction is shown.



Show your working.

$$\Delta H_r = \begin{array}{c} \text{.....} \\ \text{sign} \end{array} \begin{array}{c} \text{.....} \\ \text{value} \end{array} \text{ kJ mol}^{-1} \quad [1]$$

[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 FA 9** contains one cation and one anion. The cation is one of calcium, magnesium, manganese(II) or zinc. The anion is oxide or carbonate.

- (a)** Describe reactions to identify **FA 9**. You are advised to test for the anion first.
State any conditions needed for these reactions.

Carry out your reactions and record all your observations.
Deduce the formula of **FA 9**.

FA 9 is

[4]

- (b) (i) **FA 10** is a solution of a double salt. It contains two cations and one anion, all of which are listed in the Qualitative analysis notes.

Use a 1 cm depth of this solution of **FA 10** in a test-tube for Tests 1–3.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add an equal volume of FA 2 , aqueous potassium iodide, then	
add FA 5 , aqueous starch.	
Test 2 Add aqueous barium chloride (or barium nitrate), then	
add dilute hydrochloric acid (or nitric acid).	
Test 3 Add aqueous silver nitrate, then	
add aqueous ammonia.	
Test 4 In a boiling tube, add aqueous sodium hydroxide to a 1 cm depth of solution of FA 10 , then	
warm gently and carefully, then	
remove from heat and add one piece of aluminium foil to the mixture.	

[5]

- (ii) Identify the three ions in **FA 10** by writing the formula of each ion.

The three ions are and and

[2]

- (iii) Identify the **two** tests in (b)(i) that involve redox reactions.
Justify your answer for **one** of the tests.

Tests and involve redox reactions.

justification

.....

..... [2]

- (iv) Give an ionic equation for the reaction of **one** of the ions in **FA 10** with sodium hydroxide in **Test 4**. Include state symbols.

..... [1]

[Total: 14]

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	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ 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																							
		Key																							
		atomic number atomic symbol name relative atomic mass																							
3	4															5	6	7	8	9	10	11	12		
Li lithium 6.9	Be beryllium 9.0															B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2				
11	12															13	14	15	16	17	18				
Na sodium 23.0	Mg magnesium 24.3															Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9				
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36								
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8								
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54								
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3								
55	56	57–71 lanthanoids		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86							
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	Rn radon —								
87	88	89–103 actinoids		104	105	106	107	108	109	110	111	112	113	114	115	116	117	118							
Fr francium —	Ra radium —			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —							

lanthanoids

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 —

actinoids



Cambridge International AS & A Level

CANDIDATE
NAME

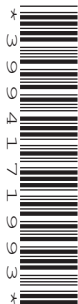
--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--



CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

October/November 2023

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 **16** pages. Any blank pages are indicated.

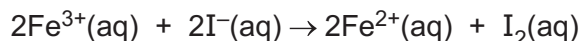
Quantitative analysis

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

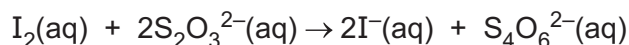
Show the precision of the apparatus you used in the data you record.

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

1 Iron(III) ions, Fe^{3+} , can oxidise iodide ions, I^- , to iodine, I_2 .



It is possible to determine the rate of this reaction by measuring the time to produce a certain amount of iodine. To do this, thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, are added to the reaction mixture. The thiosulfate ions react immediately with the iodine produced by the reaction and convert it back to iodide ions.



Iodine remains in the solution when all the thiosulfate ions have reacted. The remaining iodine is detected by starch indicator in the reaction mixture, which causes the solution to turn blue-black.

In this experiment you will investigate how the rate of the reaction between iron(III) ions and iodide ions is affected by the concentration of the iron(III) ions.

FB 1 is $0.0500 \text{ mol dm}^{-3}$ acidified iron(III) chloride, FeCl_3 .

FB 2 is $0.0500 \text{ mol dm}^{-3}$ potassium iodide, KI .

FB 3 is $0.00500 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FB 4 is starch indicator.

(a) Method

Experiment 1

- Fill the burette labelled **FB 1** with **FB 1**.
- Run 20.00 cm^3 of **FB 1** into a 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to add the following to the **other** 100 cm^3 beaker:
 - 10.0 cm^3 of **FB 2**
 - 20.0 cm^3 of **FB 3**
 - 10.0 cm^3 of **FB 4**.
- Add the contents of the first beaker to the second beaker and start timing **immediately**. Ignore any initial colouration on mixing.
- Stir the mixture once and place the beaker on the white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Rinse both beakers and shake dry.
- Rinse and dry the glass rod.

Experiment 2

- Fill the other burette with distilled water.
- Run 10.00 cm³ of **FB 1** into a 100 cm³ beaker.
- Run 10.00 cm³ of distilled water into the same beaker containing **FB 1**.
- Use the 25 cm³ measuring cylinder to add the following to the **other** 100 cm³ beaker:
 - 10.0 cm³ of **FB 2**
 - 20.0 cm³ of **FB 3**
 - 10.0 cm³ of **FB 4**.
- Add the contents of the first beaker to the second beaker and start timing **immediately**. Ignore any initial colouration on mixing.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Rinse both beakers and shake dry.
- Rinse and dry the glass rod.

Experiments 3 to 5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of **FB 1**.

The combined volume of **FB 1** and distilled water must always be 20.00 cm³.
Do **not** use a volume of **FB 1** that is less than 5.00 cm³.

The rate of reaction is given by the following expression.

$$\text{rate} = \frac{1000}{\text{reaction time in seconds}}$$

Use this expression to calculate the rate for each of your experiments.

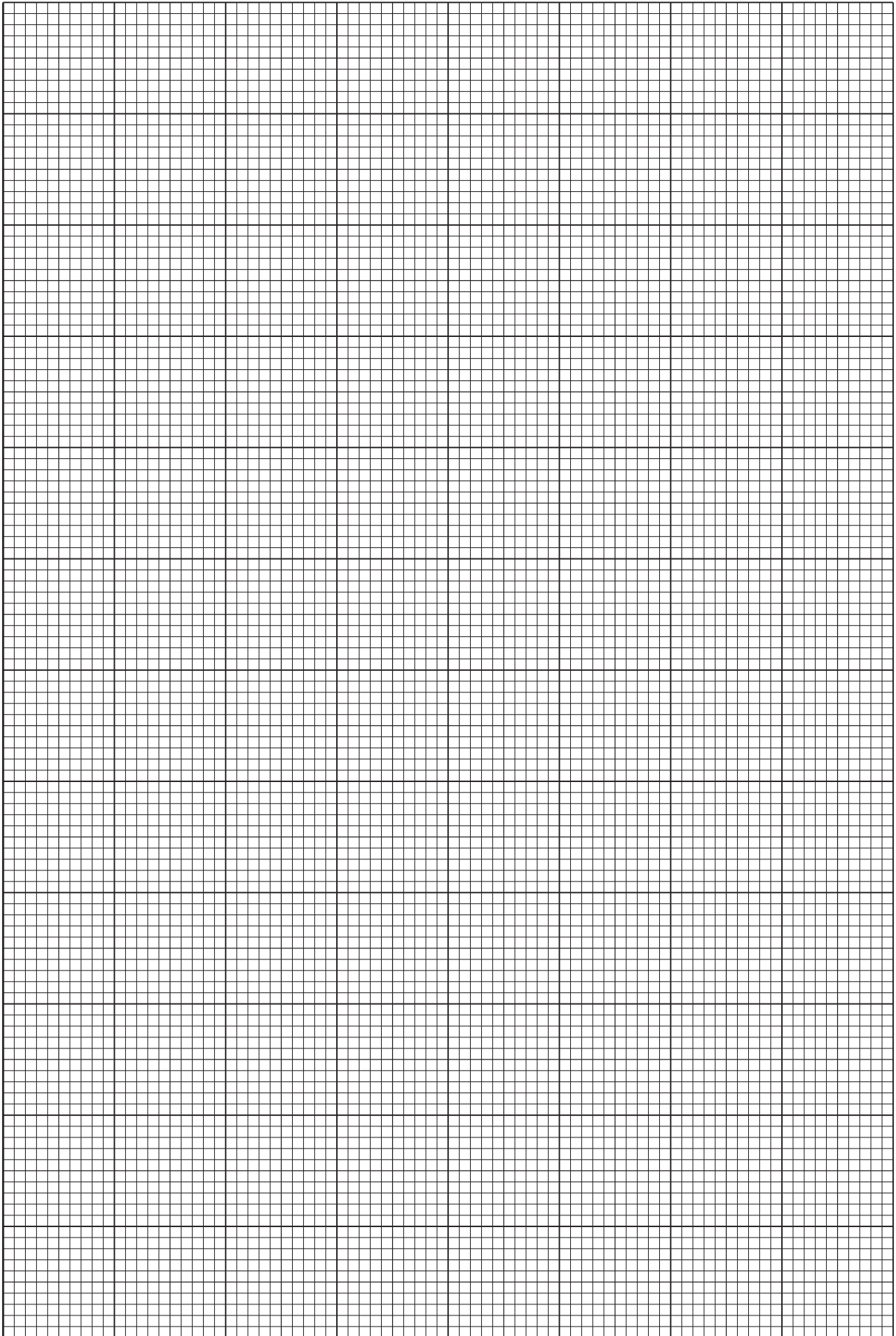
Record all your results in a single table. You should include the volume of **FB 1**, the volume of distilled water, the reaction time and the rate of reaction.

Results

I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	

[9]

- (b) On the grid opposite, plot the rate (on the y-axis) against the volume of **FB 1** (on the x-axis). Include the origin in your plot. Label any points that you consider to be anomalous. Draw the line of best fit.



I	
II	
III	
IV	

[4]

- (c) In these experiments, the volume of **FB 1** is directly related to the concentration of iron(III) ions.

Using your graph, state what conclusion can be drawn about the relationship between the rate of reaction and the concentration of the iron(III) ions.

.....
 [1]

- (d) A student wants to increase the concentration of the sodium thiosulfate solution while keeping the rest of the experiment the same. The student realises that the amount of thiosulfate ions must not be too high otherwise there will be no remaining iodine.

You will calculate the concentration of thiosulfate ions that will react with all the iodine produced in **Experiment 1**.

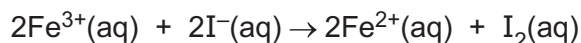
- (i) Calculate the amount, in mol, of iron(III) ions in the solution at the start of **Experiment 1**.

amount of Fe^{3+} = ... mol [1]

- (ii) Calculate the amount, in mol, of iodide ions in the solution at the start of **Experiment 1**.

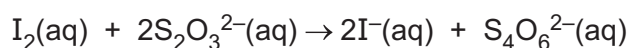
amount of I^- = ... mol [1]

- (iii) Use the equation to determine the maximum amount, in mol, of iodine that can be made during this reaction.



amount of I_2 = ... mol [1]

- (iv) Use the equation to determine the concentration, in mol dm^{-3} , of sodium thiosulfate solution that will react with all the iodine produced in **Experiment 1**.
 Show your working.



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

[Total: 19]

BLANK PAGE

- 2 In this experiment you will determine the relative formula mass of an unknown ion, $\mathbf{A}^{2-}$. The ion is present in a salt with the formula $\text{Na}_2\mathbf{A}\cdot 5\text{H}_2\text{O}$.

You will first determine the enthalpy change of solution, ΔH_{sol} , for $\text{Na}_2\mathbf{A}\cdot 5\text{H}_2\text{O}$. To do this you will measure the temperature change when a known mass of the salt dissolves in a known volume of water. You will then use a literature value for the enthalpy change of solution to calculate the relative formula mass of $\mathbf{A}^{2-}$.

FB 5 is the salt, $\text{Na}_2\mathbf{A}\cdot 5\text{H}_2\text{O}$.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Rinse the 25 cm^3 measuring cylinder with distilled water.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of distilled water into the cup.
- Weigh the stoppered container with the **FB 5**. Record the mass.
- Measure and record the initial temperature of the water in the cup. You may need to tilt the cup to make sure that the bulb of the thermometer is covered.
- Carefully add all the sample of **FB 5** to the water in the cup.
- Stir the mixture and record the minimum temperature that is reached.
- Weigh the stoppered container and any residual **FB 5**. Record the mass.
- Calculate and record the mass of **FB 5** added to the water and the change in temperature.

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the energy change in the reaction.

energy change = ... J [1]

- (ii) A literature value for the enthalpy change of solution, ΔH_{sol} , for $\text{Na}_2\text{A} \cdot 5\text{H}_2\text{O}$ is $+47.4 \text{ kJ mol}^{-1}$.

Calculate the amount, in mol, of $\text{Na}_2\text{A} \cdot 5\text{H}_2\text{O}$ in your sample of **FB 5**.

Assume that the literature value was measured under the same conditions as your experiment.

amount of $\text{Na}_2\text{A} \cdot 5\text{H}_2\text{O}$ = ... mol [1]

- (iii) Calculate the relative formula mass of A^{2-} .

relative formula mass of A^{2-} = ... [1]

- (c) A student suggests that the experiment can be made more accurate by increasing the volume of water used.

State whether the student is correct. Explain your answer.

.....

..... [1]

[Total: 8]

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 **FB 6** is a salt which contains a cation and an anion from those listed in the Qualitative analysis notes.

FB 7 is a mixture of two acids. The possible acids are hydrochloric acid, nitric acid and sulfuric acid.

By carrying out the following tests you will identify the ions in **FB 6** and determine which acids are present in **FB 7**.

(a) Carry out the following tests and record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Place approximately one third of the sample of FB 6 in a hard-glass test-tube and heat strongly, then	
leave to cool.	
Test 2 To an approximately 2 cm depth of FB 7 in a boiling tube add carefully the remaining sample of FB 6 . Keep this solution for use in 3(b).	

- (b) (i) Choose reagents and carry out tests to identify the cation in **FB 6**.
Record your tests and observations.

[2]

- (ii) State the formulae of the ions present in **FB 6**.

FB 6 contains and [1]

- (c) (i) Choose reagents and carry out tests to identify which of the following acids are present in **FB 7**. Use a 1 cm³ depth of **FB 7** for each test.
Record your observations.

test for hydrochloric acid

observations

.....

test for nitric acid

observations

.....

test for sulfuric acid

observations

.....

[4]

- (ii) State the formulae of the acids present in **FB 7**.

FB 7 contains and [1]

- (iii) Give an ionic equation for any of the reactions you observed in (c)(i). Include state symbols.

..... [1]

[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	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ 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	Key										13	14	15	16	17	18	
		1 H hydrogen 1.0																
3 Li lithium 6.9	4 Be beryllium 9.0	atomic number atomic symbol name relative atomic mass										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	3 Sc scandium 45.0	4 Ti titanium 47.9	5 V vanadium 50.9	6 Cr chromium 52.0	7 Mn manganese 54.9	8 Fe iron 55.8	9 Co cobalt 58.9	10 Ni nickel 58.7	11 Cu copper 63.5	12 Zn zinc 65.4	13 Al aluminum 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	
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		
actinoids		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 —		

anthanoids

actinoids



Cambridge International AS & A Level

CANDIDATE
NAME

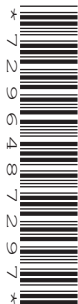
--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--



CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

October/November 2023

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

Total

This document has **12** pages.

Quantitative analysis

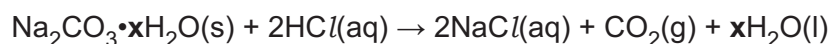
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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 You will determine the value of **x** in hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$. **x** is **not** an integer.

You will carry out two methods to determine the value of **x**. Each method involves sodium carbonate reacting with excess hydrochloric acid to release carbon dioxide.



(a) Experiment 1

You will measure the volume of carbon dioxide released when hydrated sodium carbonate reacts with excess hydrochloric acid.

FA 1 is $0.500 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FA 2 is hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

Method

- Weigh the container with **FA 2**. Record the mass.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder completely with water. Holding 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 cm^3 measuring cylinder, transfer 50.0 cm^3 of **FA 1** into the flask labelled **Z**. Check that the bung fits tightly into the neck of flask **Z**, clamp flask **Z** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip all the **FA 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. You may need to shake the flask quite vigorously until the gas formed starts to collect in the measuring cylinder.
- Return the flask to the clamp. Leave for several minutes, shaking the flask occasionally.
- Weigh the container with any residual **FA 2**. Record the mass.
- Calculate the mass of **FA 2** added to the flask. Record the mass.
- When no more gas is collected, measure the final volume of gas in the measuring cylinder. Record the volume.

Results

I	
II	
III	

[3]

(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder at room conditions.

amount of CO_2 = ... mol

Hence deduce the amount, in mol, of sodium carbonate present in the **FA 2** you added in your experiment.

amount of Na_2CO_3 = ... mol
[1]

- (ii) Use your answer to (b)(i) and the mass of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, you used in **Experiment 1** to calculate the relative formula mass, M_r , of the $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

M_r of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ = ... [1]

- (iii) Use your answer to (b)(ii) to calculate the value of x in the $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.
Show your working.

x = ... [2]

(c) A student suggests that it would be better to use hot water in the tub.

(i) State whether using hot water would be an improvement. Explain your answer.

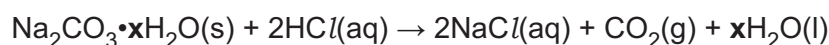
.....
 [1]

(ii) State the effect, if any, that using hot water would have on the value of **x** calculated.

.....
 [1]

(d) **Experiment 2**

You will carry out a titration to measure the volume of hydrochloric acid that neutralises an aqueous solution of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.



FA 3 is $0.100 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FA 4 is an aqueous solution containing 14.30 g dm^{-3} of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

FA 5 is bromophenol blue indicator.

Method

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add a few drops of **FA 5**.
- Carry out a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure your recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (e) 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 **FA 4** required cm³ of **FA 3**. [1]

(f) Calculations

- (i) Give your answers to **(f)(ii)**, **(f)(iii)** and **(f)(iv)** to an appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of hydrochloric acid present in the volume of **FA 3** you calculated in **(e)**.

amount of HCl = ... mol [1]

- (iii) Use the equation for the neutralisation to deduce the amount, in mol, of sodium carbonate present in 25.0 cm³ of Na₂CO₃·xH₂O.

amount of Na₂CO₃ = ... mol

Hence calculate the amount, in mol, of sodium carbonate in 1.00 dm³ of Na₂CO₃·xH₂O.

amount of Na₂CO₃ in 1.00 dm³ = ... mol [1]

- (iv) Calculate the value of **x** in the sample of Na₂CO₃·xH₂O.
Show your working.

x = ... [1]

- (g) The aqueous solution of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, **FA 4**, was prepared by weighing and dissolving the solid to make 1.00 dm^3 of solution.

Mass of container + $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$	= 32.509 g
Mass of empty container	= 18.209 g
Mass of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$	= 14.300 g

- (i) State the maximum uncertainty in a single balance reading for the balance used.

maximum uncertainty = $\pm$ g

Calculate the maximum percentage uncertainty in this mass of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.
Show your working.

maximum percentage uncertainty = $\pm$ %
[1]

- (ii) Using the method in **Experiment 2** a student calculated the relative formula mass, M_r , of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ to be 242.2. Assume that the uncertainty in the mass of **FA 4** is the only source of error in the experiment.

Calculate the maximum value for the relative formula mass of **FA 4**.

maximum value for the relative formula mass of **FA 4** = ... [1]

[Total: 23]

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.

- 2 (a) FA 6, FA 7 and FA 8** are salts each of which contains nitrogen. Each of the nitrogen-containing ions is different and all are shown in the Qualitative analysis notes.

- (i) List the nitrogen-containing ions for which you will test.

..... and and

Select reagents to positively identify the nitrogen-containing ions in each salt. Record your tests and the results with each salt in a suitable table in the space below.

[8]

- (ii) Use your observations in (a)(i) to determine the formulae of the nitrogen-containing ions present in **FA 6**, **FA 7** and **FA 8**.

FA 6 **FA 7** **FA 8** [1]

- (b) **FA 9** and **FA 10** contain the same element. You will identify this element by carrying out tests.

(i) **Test 1**

Heat a small spatula measure of **FA 9** in a hard-glass test-tube. Heat until the reaction stops.

After heating, leave the tube to cool and keep it for Test 2. You may wish to start (b)(ii) while you wait.

Record your observations.

.....

Name **one** product of the reaction.

product

Test 2

To the cooled solid product of **Test 1**, add a 2–3 cm depth of distilled water. Shake the test-tube and then leave the contents to settle.

Record your observations.

.....

[3]

- (ii) To a **very small** spatula measure of **FA 9** in a test-tube, add about a 2 cm depth of dilute sulfuric acid and about a 2 cm depth of distilled water. Shake to dissolve the **FA 9** and produce **FA 9(aq)**.

You will use **FA 9(aq)** in **Test 3** and **Test 4**.

Test 3

To a 1 cm depth of aqueous iron(II) sulfate in a test-tube, add a few drops of **FA 9(aq)**.

Record your observations.

.....

Test 4

To a 1 cm depth of aqueous potassium iodide in a test-tube, add a few drops of **FA 9**(aq).

Record your observations.

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

- (iii) To a small spatula measure of **FA 10** in a test-tube, add distilled water to dissolve the **FA 10**. This solution is **FA 10**(aq).

To a 1 cm depth of **FA 10**(aq), add aqueous sodium hydroxide.

Record your observations.

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

- (iv) Identify the element that is present in **FA 9** and **FA 10**.

element [1]

[Total: 17]

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	Key														17	18	
		atomic number atomic symbol relative atomic mass												1 H hydrogen 1.0				
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 —



Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY

9701/36

Paper 3 Advanced Practical Skills 2

October/November 2023

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 When hydrogen peroxide is decomposed by a suitable catalyst, oxygen and water are produced. You will determine the concentration of a solution of hydrogen peroxide by decomposing it and measuring the mass of oxygen produced.

FB 1 is aqueous hydrogen peroxide, H_2O_2 .

FB 2 is the catalyst, manganese(IV) oxide, MnO_2 .

(a) Method

- Use the measuring cylinder to transfer 25.0 cm^3 of **FB 1** into a conical flask.
- Weigh the conical flask containing **FB 1**. Record the mass.
- Weigh the container with **FB 2**. Record the mass.
- Tip all the **FB 2** into the conical flask. Swirl the flask gently.
- Weigh the container with any residual **FB 2**. Record the mass.
- Calculate the mass of **FB 2** added. Record the mass.
- Leave the conical flask and its contents to stand for 30 minutes. Swirl the flask occasionally.

While the reaction is taking place, begin work on Question 2 or Question 3.

- When the reaction is complete, weigh the flask and its contents. Record the mass.

You will use FB 1 in Questions 2 and 3.

I	
II	
III	

[3]

(b) Calculations

- (i) Calculate the mass of oxygen liberated.

mass of oxygen = ... g [1]

- (ii) Give the equation for the decomposition of hydrogen peroxide in (a). Include state symbols.

..... [1]

- (iii) Calculate the concentration, in mol dm^{-3} , of hydrogen peroxide in **FB 1**.

concentration of H_2O_2 in **FB 1** = ... mol dm^{-3} [2]

- (iv) The “**volume strength**” of hydrogen peroxide is equal to the volume of oxygen, in dm^3 , produced at room conditions, when 1.00 dm^3 of a solution of hydrogen peroxide is completely catalytically decomposed.

Use your answer in (b)(iii) to calculate the volume, in dm^3 , of oxygen produced when 1.00 dm^3 of **FB 1** decomposes at room conditions. Your answer to this calculation is numerically equal to the “volume strength”, in vol, of solution **FB 1**. Show your working.

“volume strength” of H_2O_2 in **FB 1** = ... vol [1]

- (c) (i) Describe the observation to determine whether or not the decomposition of hydrogen peroxide in **FB 1** is complete.
Explain your answer.

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

- (ii) A student suggests that the experiment in (a) would be more accurate if a loose-fitting plug of cotton wool was pushed gently into the mouth of the conical flask during the reaction.

State whether the student is correct. Explain your answer.

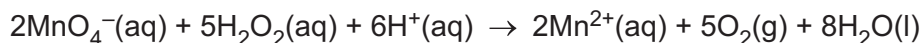
.....
.....
..... [2]

- (iii) Deduce the mass of manganese(IV) oxide, **FB 2**, left in the conical flask at the end of the experiment. Explain your answer.

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

[Total: 12]

- 2 The concentration of a solution of hydrogen peroxide can also be determined by titration with acidified potassium manganate(VII). The equation for the reaction is shown below.



FB 1 is aqueous hydrogen peroxide, H_2O_2 .

FB 3 is $0.0180\text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FB 4 is dilute sulfuric acid, H_2SO_4 .

(a) Method

Dilution of FB 1

- Pipette 10.0 cm^3 of **FB 1** into the 250 cm^3 volumetric flask.
- Make the solution up to the mark using distilled water.
- Shake the flask thoroughly.
- This diluted solution of hydrogen peroxide is **FB 5**.

Titration

- Fill the burette with **FB 3**.
- Pipette 25.0 cm^3 of **FB 5** into a clean conical flask.
- Rinse out the measuring cylinder with distilled water. Use the measuring cylinder to transfer 20 cm^3 of **FB 4** into the same flask.
- 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 **FB 3** 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 obtained the mean value.

25.0 cm³ of **FB 5** required cm³ of **FB 3**. [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 potassium manganate(VII) present in the volume of **FB 3** calculated in (b).

amount of KMnO₄ = ... mol [1]

- (iii) Use your answer to (c)(ii) and the equation on page 4 to calculate the amount, in mol, of hydrogen peroxide in **FB 5** used in each titration.

amount of H₂O₂ = ... mol [1]

- (iv) Calculate the concentration of hydrogen peroxide in **FB 1**, in mol dm⁻³.

concentration of H₂O₂ in **FB 1** = ... mol dm⁻³ [1]

- (d) (i) State which procedure, the method you used in **1(a)** or the method you used in **2(a)**, gives a more accurate value for the concentration of H₂O₂ in **FB 1**. Explain your answer.

.....

 [1]

- (ii) The uncertainty in reading a 25 cm³ pipette is ±0.06 cm³. Explain why this pipette is more accurate than a burette for measuring 25.0 cm³ of a solution.

.....

 [1]

[Total: 14]

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 a solution containing one cation and one anion. The anion is listed in the Qualitative analysis notes.

FB 7 is aqueous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

- (i) To a 1 cm depth of **FB 7** in a test-tube, add an equal volume of **FB 6**.
Record the first change you observe.
Wash out your test-tube with plenty of tap water as soon as you finish this test.

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

- (ii) Carry out tests to identify the anion in **FB 6**. The anion does **not** contain carbon or sulfur.
Record details of your tests and all your observations in a suitable form below.

[3]

- (iii) Give the formula of **FB 6**.

FB 6 is [1]

(b) **FB 8** is a solution containing one cation and one anion, both of which are listed in the Qualitative analysis notes.

FB 1 is aqueous hydrogen peroxide.

(i) Use a 1 cm depth of **FB 8** for the following tests. Record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observation</i>
Test 1 Add aqueous ammonia.	
Test 2 Add aqueous barium nitrate or aqueous barium chloride, then	
add dilute hydrochloric acid.	
Test 3 Add an equal volume of FB 1 , then	
add aqueous sodium hydroxide.	
Test 4 Add a few drops of acidified aqueous potassium manganate(VII).	

[5]

(ii) Give the ionic equation for the reaction of **FB 8** in **Test 1**. Include state symbols.

..... [2]

(iii) **Test 3** involves a redox reaction.

Using your observations, justify the statement that a redox reaction has taken place.

.....

 [2]

[Total: 14]

BLANK PAGE

BLANK PAGE

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

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	euporium	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
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	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	—

lanthanoids

actinoids