



Cambridge International AS & A Level

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

October/November 2024

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 The neutralisation of an acid by an alkali is an exothermic reaction. The concentration of an acid can be found by measuring the temperature change when the acid reacts with an alkali.

You will determine the concentration of sulfuric acid by adding aqueous sodium hydroxide of known concentration to the sulfuric acid and measuring the temperature change.

FA 1 is 2.01 mol dm^{-3} sodium hydroxide, NaOH.

FA 2 is sulfuric acid, H_2SO_4 .

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Pipette 25.0 cm^3 of **FA 1** into the cup.
- Place the thermometer into the **FA 1** in the cup. Tilt the cup if necessary to ensure the bulb of the thermometer is fully covered. Record the temperature of **FA 1** in Table 1.1. This is the temperature when the volume of **FA 2** is 0.00 cm^3 .
- Fill the burette with **FA 2**.
- Run 5.00 cm^3 of **FA 2** into the cup containing **FA 1**.
- Stir the mixture and record the maximum temperature in Table 1.1.
- Run further 5.00 cm^3 portions of **FA 2** into the same cup.
- After each addition of **FA 2** stir the contents of the cup. Record the maximum temperature for each addition.

Table 1.1

total volume of FA 2 / cm^3	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
temperature / $^{\circ}\text{C}$									

I	
II	
III	
IV	

[4]

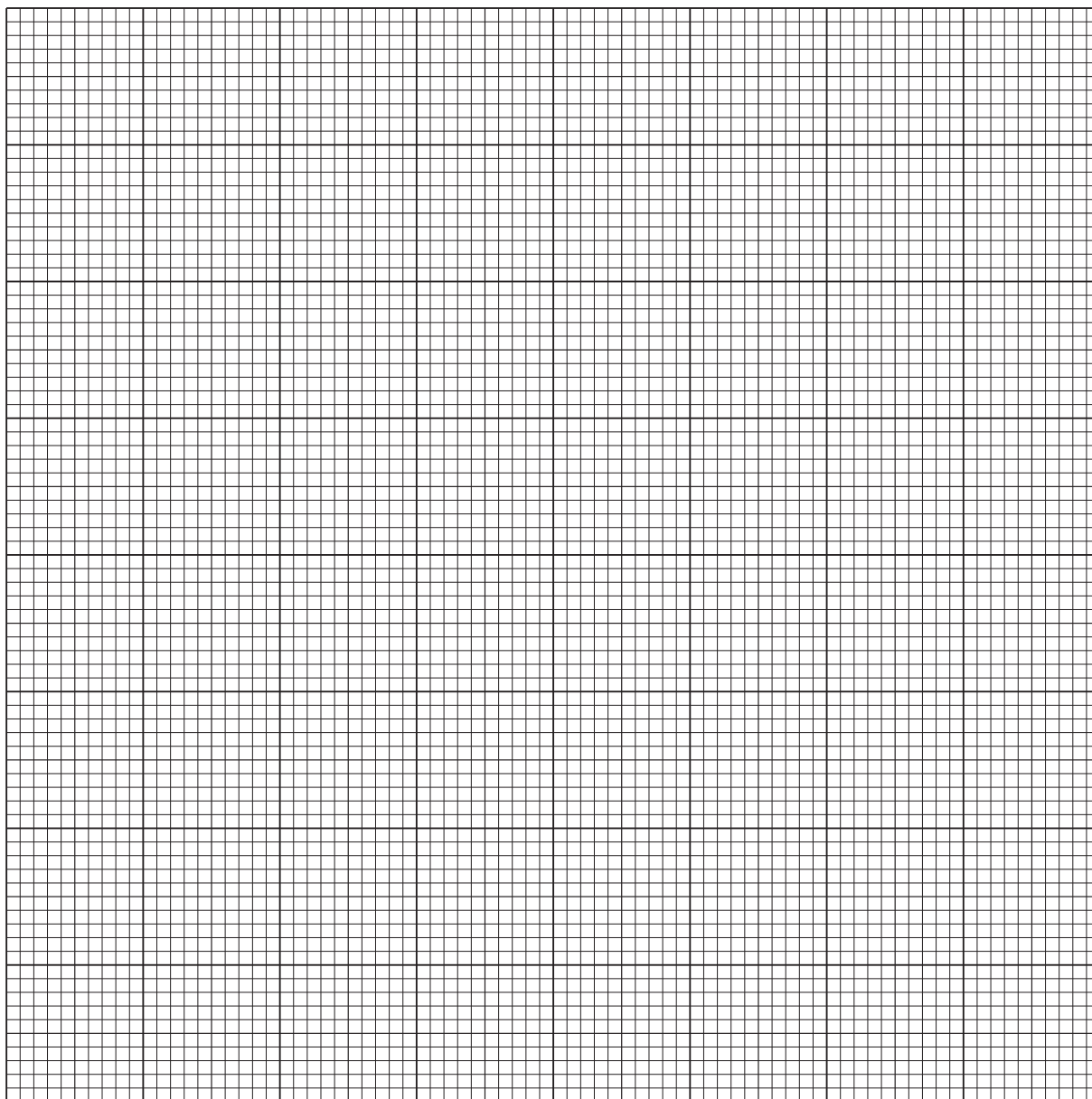
Keep the rest of **FA 2** for use in Question 2.





- (b) Plot a graph of temperature of solution (y-axis) against total volume of **FA 2** added (x-axis) on the grid. Select a scale for the y-axis to include a value 3 °C above your maximum temperature reading. Label any points you consider to be anomalous.

Draw **two** lines of best fit through the points on your graph. Draw the first line for the increase in temperature and the second line after the maximum temperature was reached. Extrapolate the lines so they intersect. This intersection corresponds to the volume of **FA 2** needed to neutralise the **FA 1** in your experiment in (a).



I	
II	
III	
IV	
V	

25.0 cm³ of **FA 1** required cm³ of **FA 2**.

[5]

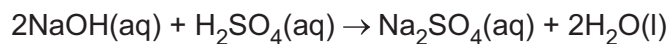




(c) (i) Calculate the amount, in mol, of sodium hydroxide, **FA 1**, pipetted into the cup.

amount of NaOH = ... mol [1]

(ii) The equation for this neutralisation reaction is shown.



Calculate the concentration, in mol dm^{-3} , of sulfuric acid in **FA 2**.

Show your working.

concentration of H_2SO_4 = ... mol dm^{-3}
[2]

[Total: 12]





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2 Acids react with carbonates to produce carbon dioxide gas.



This reaction can be used to determine the concentration of acid, using the mass of carbon dioxide released.

You will determine the concentration of sulfuric acid in **FA 2**.

FA 2 is the solution used in **Question 1**.

FA 3 is sodium carbonate, Na_2CO_3 .

(a) Method

- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 2** into the conical flask.
- Weigh the flask with the acid. Record the mass.
- Weigh the container with **FA 3**. Record the mass.
- Carefully tip all of **FA 3** into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand with occasional swirling until the fizzing stops.
- Weigh the container with any residual **FA 3**. Record the mass.
- Calculate and record the mass of **FA 3** added to the flask.
- Calculate and record the total mass of flask + acid + **FA 3**.
- Weigh the flask and contents when the fizzing has stopped. Record the mass.
- Calculate and record the mass of carbon dioxide given off during the experiment.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

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

amount of CO_2 = ... mol [1]





- (ii) The sodium carbonate, **FA 3**, was in excess in the reaction with sulfuric acid. Show by calculation that the sodium carbonate was in excess. Use your answer to **(b)(i)**.

[2]

- (iii) Calculate the concentration, in mol dm^{-3} , of sulfuric acid in **FA 2**.

concentration of H_2SO_4 = ... mol dm^{-3} [1]

- (c) (i) A student does not have a conical flask and uses a small beaker for the reaction. Explain why a conical flask is better.

.....

..... [1]

- (ii) Two students made suggestions of how they thought the experiment in **(a)** could be adapted to determine the concentration of sulfuric acid, **FA 2**, by using other reactions. In each case their teacher told them that this method was not suitable.

Explain, in each case, why the method is **not** suitable. Do **not** consider factors based on quantities of any reagent.

Student 1 suggested using magnesium in place of sodium carbonate.

.....

.....

Student 2 suggested using calcium carbonate in place of sodium carbonate.

.....

.....

[3]





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

uncertainty = $\pm$ g

Calculate the maximum percentage error in the mass of **FA 3** that you weighed out in (a).

maximum percentage error = ... % [1]

[Total: 14]

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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. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

3 FA 4, FA 5 and FA 6 are compounds of the same metal in different oxidation states.

- (a) (i) Place a small spatula measure of **FA 4** in a hard-glass test-tube. Heat the tube gently at first and then more strongly.

Record all your observations.

Leave the tube and contents to cool and keep for use in (a)(iii).

.....

.....

.....

..... [2]





- (ii) Dissolve a **small** spatula measure of **FA 4** in approximately 5 cm depth of distilled water in a boiling tube and add approximately 1 cm depth of dilute sulfuric acid.

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

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of aqueous FA 4 in a test-tube add aqueous iron(II) sulfate.	
Test 2 To a 1 cm depth of aqueous FA 4 in a test-tube add hydrogen peroxide.	

[2]

- (iii) To the cooled test-tube in (a)(i) add a 5 cm depth of distilled water. Observe and record the colour formed.

..... [1]



- (b) Dissolve a small spatula measure of **FA 5** in a boiling tube half-filled with distilled water. Warming may be needed to dissolve the **FA 5**.

Carry out the following tests and record your observations in Table 3.2.

For each of the tests use a 1 cm depth of this **FA 5** solution in a test-tube.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 Add dilute nitric acid, then	
add aqueous silver nitrate.	
Test 2 Add aqueous barium chloride or barium nitrate, then	
add dilute nitric acid.	
Test 3 Add aqueous sodium hydroxide, then	
add hydrogen peroxide.	

[3]





- (c) Carry out the following tests and record your observations in Table 3.3. Identify any gases produced.

For each of the tests use a small spatula measure of **FA 6** in a test-tube.

Table 3.3

<i>test</i>	<i>observations and gases produced</i>
Test 1 Add a 1 cm depth of dilute nitric acid.	
Test 2 Add a few drops of concentrated hydrochloric acid. CARE Hydrochloric acid is corrosive. Fill the test-tube with water as soon as you have made your observation.	
Test 3 Add a 1 cm depth of hydrogen peroxide.	

[3]

- (d) (i) Use your observations from the tests on **FA 4**, **FA 5** and **FA 6** to suggest the identity of the metal present in all 3 compounds.

Metal identity

[1]

- (ii) Identify the oxidation state of the metal in each compound.

FA 4

FA 5

FA 6

[2]

[Total: 14]





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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	Key														17	18
		atomic number atomic symbol name relative atomic mass															
3	4																
Li lithium 6.9	Be beryllium 9.0	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
11	12																
Na sodium 23.0	Mg magnesium 24.3	B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2										
19	20	31	32	33	34	35	36										
K potassium 39.1	Ca calcium 40.1	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	49	50	51	52	53	54										
Rb rubidium 85.5	Sr strontium 87.6	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	81	82	83	84	85	86										
Cs caesium 132.9	Ba barium 137.3	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —										
87	88	113	114	115	116	117	118										
Fr francium —	Ra radium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —										



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CHEMISTRY**9701/33**

Paper 3 Advanced Practical Skills 1

October/November 2024**2 hours**

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Session

Laboratory

For Examiner's Use

1	
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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 answer to **each** step of your calculations.

- 1 When a metal carbonate reacts with a suitable acid, carbon dioxide is produced. You will determine the relative formula mass, M_r , of a metal carbonate by reacting it with excess hydrochloric acid and measuring the mass of gas produced.

FA 1 is the metal carbonate.

FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl .

(a) Method

- Use the measuring cylinder to transfer 30.0 cm^3 of **FA 2** into a conical flask.
- Weigh the conical flask containing **FA 2**. Record the mass.
- Weigh the container with **FA 1**. Record the mass.
- Tip all the **FA 1** slowly into the conical flask. When the reaction slows, swirl the flask gently.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate the mass of **FA 1** added. Record the mass.
- Leave the conical flask and its contents for 15 minutes. Swirl the flask occasionally during this time.

During this period begin work on Question 2.

- After 15 minutes weigh the flask and its contents. Record the mass.

I	
II	
III	

[3]

(b) Calculations

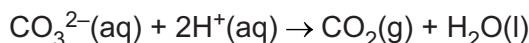
- (i) Use your readings to calculate the mass of carbon dioxide produced.

mass of $\text{CO}_2 = \dots\dots\dots \text{g}$ [1]





- (ii) The ionic equation for the reaction of **FA 1** with **FA 2** is shown.



Calculate the relative formula mass, M_r , of the metal carbonate **FA 1**. Show your working.

M_r of **FA 1** = ... [2]

- (c) (i) A student carries out the experiment as described in (a), except that the acid used is 15°C colder than the acid you used. The student calculates the M_r correctly from the readings obtained.

State whether the value of the M_r calculated by the student is higher or lower than the value you calculated in (b)(ii). Explain your answer.

..... [2]

- (ii) Another student suggests that the experiment will be more accurate if the conical flask is tilted carefully to an almost horizontal position while the reaction is taking place.

Explain why the student is correct.

..... [1]

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

uncertainty = $\pm$ g

Give an expression that would enable you to calculate the percentage error in your weighing of **FA 1**.

[1]

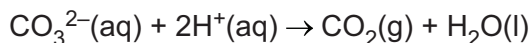
[Total: 10]

[Turn over]





- 2 The relative formula mass, M_r , of metal carbonate **FA 1** can also be determined by titration of a solution of **FA 1** with an acid such as hydrochloric acid.



FA 3 is an aqueous solution of **FA 1** containing 15.50 g dm^{-3} of the metal carbonate.

FA 4 is a solution of hydrochloric acid containing 4.02 g dm^{-3} of HCl .

FA 5 is bromophenol blue indicator.

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add a few drops of **FA 5** into the same conical 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 all your burette readings and the volume of **FA 4** added in each accurate titration.

I	
II	
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IV	
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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.

25.0 cm^3 of **FA 3** required cm^3 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 hydrochloric acid present in the volume of **FA 4** calculated in **(b)**.

amount of HCl = ... mol [1]

- (iii) Calculate the concentration, in mol dm^{-3} , of metal carbonate in **FA 3**.

concentration of metal carbonate in **FA 3** = ... mol dm^{-3} [1]

- (iv) Calculate the relative formula mass, M_r , of the metal carbonate in **FA 1**.

M_r of metal carbonate = ... [1]

- (v) The metal carbonate in **FA 1** is hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$. Calculate the value of **x** to the nearest whole number. Show your working.

x = ... [1]

- (d) Describe a different method to determine the value of **x** in **FA 1**. This method should **not** involve the reaction of an acid. Explain how the method will ensure that the value of **x** is as accurate as possible.

.....

.....

.....

.....

.....

..... [2]





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. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

- 3 (a) (i)** **FA 6** contains one cation and one anion both of which are listed in the Qualitative analysis notes.

Heat a small spatula measure of **FA 6** in a hard-glass test-tube, until no further change occurs.

Record **all** your observations. Identify any gas produced.

.....

.....

.....

.....

..... [3]

- (ii)** Allow the residue to cool for 2 minutes. Then transfer a **small** quantity of the residue from **(a)(i)** into a test-tube containing a 2 cm depth of dilute sulfuric acid. Shake the test-tube.

Record your observations.

.....

..... [1]

- (iii)** Give the equation for the reaction in **(a)(ii)**.
Include state symbols.

..... [1]





- (b) **FA 7** is a sample of the solution produced by the experiment described in (a)(ii).
FA 8 is a solution of a salt containing one anion.

- (i) Use a 1 cm depth of **FA 7** in a test-tube for each of the following tests.
 Record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide.	
Test 2 Add aqueous ammonia, then add dilute hydrochloric acid.	
Test 3 Add aqueous sodium carbonate.	
Test 4 Add several drops of FA 8 , then add a few drops of aqueous starch.	
Test 5 Add a small spatula measure of iron powder. Leave the test-tube to stand.	
Test 6 Add a few drops of aqueous barium nitrate or aqueous barium chloride.	

[6]

- (ii) Carry out a different test from those you have already carried out in (b)(i) to confirm the identity of the anion in **FA 8**.
 Record the reagent(s) used and your observations and give the formula of the anion.

The formula of the anion in **FA 8** is

[2]

- (iii) List **all** the numbered tests you carried out in (b)(i) which involved redox reactions.

..... [1]





- (iv) Give the **ionic** equation for the reaction taking place in **Test 5** in (b)(i).
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	Key														17	18
		atomic number atomic symbol name relative atomic mass															
		1 H hydrogen 1.0															
		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 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	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 —





Cambridge International AS & A Level

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CHEMISTRY**9701/34**

Paper 3 Advanced Practical Skills 2

October/November 2024**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

Session	
Laboratory	

For Examiner's Use

For Examiner's Use	
1	
2	
3	
Total	

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



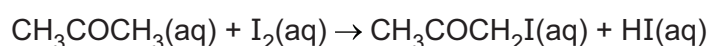
Quantitative analysis

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 answer to **each** step of your calculations.

- Iodine reacts with propanone in the presence of an acid catalyst. The rate of this reaction can be measured by determining how the concentration of iodine in the reaction mixture changes with time.

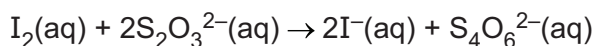


A student studies this reaction by mixing together the following three solutions and immediately starting the stop-clock.

- 100.0 cm³ of 0.1000 mol dm⁻³ iodine, I₂
- 50.0 cm³ of 1.00 mol dm⁻³ propanone, CH₃COCH₃
- 50.0 cm³ of 1.00 mol dm⁻³ sulfuric acid, H₂SO₄

The student removes 25.0 cm³ of the solution. After 80 seconds, 50.0 cm³ of a solution of sodium hydrogencarbonate, NaHCO₃, is added which reacts with all the sulfuric acid in the sample. Distilled water is added until the volume of the solution is 150.0 cm³. This solution is **FB 1**.

In this experiment you will determine the concentration of iodine in **FB 1** and so determine the average rate of reaction during the first 80 seconds. You will do this by titration using sodium thiosulfate solution.



FB 1 is a sample of the solution prepared by the student.

FB 2 is 0.0100 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

FB 3 is starch indicator.

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm³ of **FB 1** into a conical flask.
- Run **FB 2** into the conical flask until the colour of the solution turns yellow. Then add 10 drops of **FB 3**. The solution will turn blue-black.
- The end-point of the titration is when the solution turns colourless.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm³.

- 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 all your burette readings and the volume of **FB 2** added in each accurate titration.





Results

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 this value.

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

(c) Calculations

- (i) Give your answers to each part of (c)(ii) and (c)(iii) to an appropriate number of significant figures. [1]
- (ii) Use your answer to (b) to calculate the amount, in mol, of thiosulfate ions in your mean titre.

amount of $\text{S}_2\text{O}_3^{2-}$ = ... mol

Hence calculate the amount, in mol, of iodine present in the total volume of 150.0 cm³ that the student prepares.

amount of I_2 = ... mol [2]

- (iii) Calculate the concentration, in mol dm⁻³, of iodine in the sample that the student removes from the reaction mixture.

concentration of I_2 = ... mol dm⁻³ [1]





(iv) Calculate the initial concentration of iodine in the reaction mixture.

(If you were unable to determine an answer to **(c)(iii)** use $0.0315 \text{ mol dm}^{-3}$ as the concentration of I_2 in the sample the student removed.)

initial concentration of $\text{I}_2 = \dots\dots\dots \text{mol dm}^{-3}$

Hence calculate the average rate of reaction during the first 80 seconds using the formula shown.

$$\text{average rate of reaction} = \frac{\text{change in the concentration of } \text{I}_2}{\text{time}}$$

average rate = $\frac{\text{value}}{\text{units}}$ [2]

(d) Suggest why the starch solution is added when the solution in the conical flask turns yellow and not added at the start of the titration.

..... [1]

(e) A student suggests that the experimental procedure is incorrect. The student says that the sample should be removed from the reaction mixture at 80 seconds rather than the sodium hydrogencarbonate being added at 80 seconds.
State if you agree with this student. Explain your answer.

..... [1]

[Total: 16]



- 2 In this experiment you will identify the ions in the hydrated salt $\text{MA}_2 \cdot 2\text{H}_2\text{O}$, where **M** is a Group 2 metal. You will first determine the relative formula mass of the salt by measuring the mass loss when the sample is heated. Heating the sample produces the anhydrous salt and water of crystallisation. You will then select reagents to determine the identity of the ion **A**⁺.

FB 4 is the salt, $\text{MA}_2 \cdot 2\text{H}_2\text{O}$.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all of **FB 4** into the crucible.
- Weigh the crucible, lid and **FB 4**. Record the mass.
- Calculate and record the mass of **FB 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.

While the crucible is cooling, 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 mass of residue obtained.

Results

I	
II	
III	
IV	
V	

[5]

- (b)** Calculate the amount, in mol, of water lost.

amount of H_2O = ... mol

Hence calculate the relative formula mass, M_r , of MA_2 .

M_r of MA_2 = ... [2]





- (c) **FB 5** is a solution of the hydrated salt **MA₂**. The **A⁻** ion is a halide. Carry out tests to identify the halide present in **MA₂**. Record the reagents used, the results of your tests and the identity of **A⁻**.

A⁻ is

[2]

- (d) Using your answers to (b) and (c), identify the ion **M²⁺**.

M²⁺ is

[1]

- (e) A student correctly identifies **A⁻** but did not heat the sample of **FB 4** for long enough to remove all the water of crystallisation. Despite this error, the student still correctly identifies **M²⁺**.

Explain how the student's answer in (b) would differ from the true answer.

.....

Explain why the student still correctly identifies **M²⁺**.

.....

[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. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

- 3 (a) (i) FB 6** is potassium manganate(VII). Place all the **FB 6** in a hard-glass test-tube and heat gently at first and then more strongly. Record your observations.

.....

.....

..... [1]

Leave the tube to cool and keep for use in (a)(ii).

While the tube is cooling, you may wish to begin work on (b).

- (ii)** Complete Table 3.1 by carrying out the tests described. Record your observations.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 To a 7 cm depth of distilled water in a boiling tube, add approximately half of the residue from (a)(i) .	
Test 2 To a 4 cm depth of aqueous sodium hydroxide in a test-tube, add the remaining residue from (a)(i) .	

[2]

- (iii)** Suggest what type of reaction takes place in **(a)(i)**.

..... [1]





- (b) **FB 7** is a solution of a salt which contains a cation and an anion from those listed in the Qualitative analysis notes.

FB 8 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

- (i) Complete Table 3.2 by carrying out the tests described. Record your observations.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FB 7 in a test-tube, add aqueous ammonia until there is no further change, then ----- add a few drops of hydrogen peroxide.	
Test 2 To a 1 cm depth of FB 7 in a test-tube, add a 1 cm depth of aqueous potassium iodide, then ----- add FB 8 .	

[5]

- (ii) The anion in **FB 7** is either the sulfite ion or the sulfate ion. Carry out tests to identify which ion is present. Record the reagents used and the results of your tests.

[2]

- (iii) Give the formula of the salt in **FB 7**.

.....

[1]

[Total: 12]





DO NOT WRITE IN THIS MARGIN





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	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
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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

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11	Na sodium 23.0	12	Mg magnesium 24.3	3	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr	37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe	55	Cs	56	Ba	57–71	lanthanoids	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn	87	Fr	88	Ra	89–103	actinoids	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn	113	Nh	114	Fl	115	Mc	116	Lv	117	Ts	118	Og																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
19	K potassium 39.1	20	Ca calcium 40.1	4	20	Ca	47.9	Ti	50.9	V	52.0	Cr	54.9	Mn	55.8	Fe	58.9	Co	58.7	Ni	63.5	Cu	65.4	Zn	69.7	Ga	72.6	Ge	74.9	As	79.0	Se	79.9	Br	83.8	Kr	85	Rb	87.6	Sr	88.9	Y	91.2	Zr	92.9	Nb	95.9	Mo	98.9	Tc	101.1	Ru	102.9	Rh	106.4	Pd	107.9	Ag	112.4	Cd	114.8	In	118.7	Sn	121.8	Sb	127.6	Te	126.9	I	131.3	Xe	132.9	Cs	137.3	Ba	138–152	lanthanoids	153	Eu	154	Gd	155	Tb	156	Dy	157	Ho	158	Er	159	Tm	160	Yb	161	Lu	162	Hf	163	Ta	164	W	165	Re	166	Os	167	Ir	168	Pt	169	Au	170	Hg	171	Tl	172	Pb	173	Bi	174	Po	175	At	176	Rn	177	Fr	178	Ra	179	Ac	180	Th	181	Pa	182	U	183	Np	184	Pu	185	Am	186	Cm	187	Bk	188	Cf	189	Es	190	Fm	191	Mn	192	Fe	193	Co	194	Ni	195	Cu	196	Zn	197	Ga	198	Ge	199	As	200	Se	201	Br	202	Kr	203	Rb	204	Sr	205	Y	206	Zr	207	Nb	208	Mo	209	Tc	210	Ru	211	Rh	212	Pd	213	Ag	214	Cd	215	In	216	Sn	217	Sb	218	Te	219	I	220	Xe	221	At	222	Rn	223	Fr	224	Ra	225	Ac	226	Th	227	Pa	228	U	229	Np	230	Pu	231	Am	232	Cm	233	Bk	234	Cf	235	Es	236	Fm	237	Mn	238	Fe	239	Co	240	Ni	241	Cu	242	Zn	243	Ga	244	Ge	245	As	246	Se	247	Br	248	Kr	249	Rb	250	Sr	251	Y	252	Zr	253	Nb	254	Mo	255	Tc	256	Ru	257	Rh	258	Pd	259	Ag	260	Cd	261	In	262	Sn	263	Sb	264	Te	265	I	266	Xe	267	At	268	Rn	269	Fr	270	Ra	271	Ac	272	Th	273	Pa	274	U	275	Np	276	Pu	277	Am	278	Cm	279	Bk	280	Cf	281	Es	282	Fm	283	Mn	284	Fe	285	Co	286	Ni	287	Cu	288	Zn	289	Ga	290	Ge	291	As	292	Se	293	Br	294	Kr	295	Rb	296	Sr	297	Y	298	Zr	299	Nb	300	Mo	301	Tc	302	Ru	303	Rh	304	Pd	305	Ag	306	Cd	307	In	308	Sn	309	Sb	310	Te	311	I	312	Xe	313	At	314	Rn	315	Fr	316	Ra	317	Ac	318	Th	319	Pa	320	U	321	Np	322	Pu	323	Am	324	Cm	325	Bk	326	Cf	327	Es	328	Fm	329	Mn	330	Fe	331	Co	332	Ni	333	Cu	334	Zn	335	Ga	336	Ge	337	As	338	Se	339	Br	340	Kr	341	Rb	342	Sr	343	Y	344	Zr	345	Nb	346	Mo	347	Tc	348	Ru	349	Rh	350	Pd	351	Ag	352	Cd	353	In	354	Sn	355	Sb	356	Te	357	I	358	Xe	359	At	360	Rn	361	Fr	362	Ra	363	Ac	364	Th	365	Pa	366	U	367	Np	368	Pu	369	Am	370	Cm	371	Bk	372	Cf	373	Es	374	Fm	375	Mn	376	Fe	377	Co	378	Ni	379	Cu	380	Zn	381	Ga	382	Ge	383	As	384	Se	385	Br	386	Kr	387	Rb	388	Sr	389	Y	390	Zr	391	Nb	392	Mo	393	Tc	394	Ru	395	Rh	396	Pd	397	Ag	398	Cd	399	In	400	Sn	401	Sb	402	Te	403	I	404	Xe	405	At	406	Rn	407	Fr	408	Ra	409	Ac	410	Th	411	Pa	412	U	413	Np	414	Pu	415	Am	416	Cm	417	Bk	418	Cf	419	Es	420	Fm	421	Mn	422	Fe	423	Co	424	Ni	425	Cu	426	Zn	427	Ga	428	Ge	429	As	430	Se	431	Br	432	Kr	433	Rb	434	Sr	435	Y	436	Zr	437	Nb	438	Mo	439	Tc	440	Ru	441	Rh	442	Pd	443	Ag	444	Cd	445	In	446	Sn	447	Sb	448	Te	449	I	450	Xe	451	At	452	Rn	453	Fr	454	Ra	455	Ac	456	Th	457	Pa	458	U	459	Np	460	Pu	461	Am	462	Cm	463	Bk	464	Cf	465	Es	466	Fm	467	Mn	468	Fe	469	Co	470	Ni	471	Cu	472	Zn	473	Ga	474	Ge	475	As	476	Se	477	Br	478	Kr	479	Rb	480	Sr	481	Y	482	Zr	483	Nb	484	Mo	485	Tc	486	Ru	487	Rh	488	Pd	489	Ag	490	Cd	491	In	492	Sn	493	Sb	494	Te	495	I	496	Xe	497	At	498	Rn	499	Fr	500	Ra	501	Ac	502	Th	503	Pa	504	U	505	Np	506	Pu	507	Am	508	Cm	509	Bk	510	Cf	511	Es	512	Fm	513	Mn	514	Fe	515	Co	516	Ni	517	Cu	518	Zn	519	Ga	520	Ge	521	As	522	Se	523	Br	524	Kr	525	Rb	526	Sr	527	Y	528	Zr	529	Nb	530	Mo	531	Tc	532	Ru	533	Rh	534	Pd	535	Ag	536	Cd	537	In	538	Sn	539	Sb	540	Te	541	I	542	Xe	543	At	544	Rn	545	Fr	546	Ra	547	Ac	548	Th	549	Pa	550	U	551	Np	552	Pu	553	Am	554	Cm	555	Bk	556	Cf	557	Es	558	Fm	559	Mn	560	Fe	561	Co	562	Ni	563	Cu	564	Zn	565	Ga	566	Ge	567	As	568	Se	569	Br	570	Kr	571	Rb	572	Sr	573	Y	574	Zr	575	Nb	576	Mo	577	Tc	578	Ru	579	Rh	580	Pd	581	Ag	582	Cd	583	In	584	Sn	585	Sb	586	Te	587	I	588	Xe	589	At	590	Rn	591	Fr	592	Ra	593	Ac	594	Th	595	Pa	596	U	597	Np	598	Pu	599	Am	600	Cm	601	Bk	602	Cf	603	Es	604	Fm	605	Mn	606	Fe	607	Co	608	Ni	609	Cu	610	Zn	611	Ga	612	Ge	613	As	614	Se	615	Br	616	Kr	617	Rb	618	Sr	619	Y	620	Zr	621	Nb	622	Mo	623	Tc	624	Ru	625	Rh	626	Pd	627	Ag	628	Cd	629	In	630	Sn	631	Sb	632	Te	633	I	634	Xe	635	At	636	Rn	637	Fr	638	Ra	639	Ac	640	Th	641	Pa	642	U	643	Np	644	Pu	645	Am	646	Cm	647	Bk	648	Cf	649	Es	650	Fm	651	Mn	652	Fe	653	Co	654	Ni	655	Cu	656	Zn	657	Ga	658	Ge	659	As	660	Se	661	Br	662	Kr	663	Rb	664	Sr	665	Y	666	Zr	667	Nb	668	Mo	669	Tc	670	Ru	671	Rh	672	Pd	673	Ag	674	Cd	675	In	676	Sn	677	Sb	678	Te	679	I	680	Xe	681	At	682	Rn	683	Fr	684	Ra	685	Ac	686	Th	687	Pa	688	U	689	Np	690	Pu	691	Am	692	Cm	693	Bk	694	Cf	695	Es	696	Fm	697	Mn	698	Fe	699	Co	700	Ni	701	Cu	702	Zn	703	Ga	704	Ge	705	As	706	Se	707	Br	708	Kr	709	Rb	710	Sr	711	Y	712	Zr	713	Nb	714	Mo	715	Tc	716	Ru	717	Rh	718	Pd	719	Ag	720	Cd	721	In	722	Sn	723	Sb	724	Te	725	I	726	Xe	727	At	728	Rn	729	Fr	730	Ra	731	Ac	732	Th	733	Pa	734	U	735	Np	736	Pu	737	Am	738	Cm	739	Bk	740	Cf	741	Es	742	Fm	743	Mn	744	Fe	745	Co	746	Ni	747	Cu	748	Zn	749	Ga	750	Ge	751	As	752	Se	753	Br	754	Kr	755	Rb	756	Sr	757	Y	758	Zr	759	Nb	760	Mo	761	Tc	762	Ru	763	Rh	764	Pd	765	Ag	766	Cd	767	In	768	Sn	769	Sb	770	Te	771	I	772	Xe	773	At	774	Rn	775	Fr	776	Ra	777	Ac	778	Th	779	Pa	780	U	781	Np	782	Pu	783	Am	784	Cm	785	Bk	786	Cf	787	Es	788	Fm	789	Mn	790	Fe	791	Co	792	Ni	793	Cu	794	Zn	795	Ga	796	Ge	797	As	798	Se	799	Br	800	Kr	801	Rb	802	Sr	803	Y	804	Zr	805	Nb	806	Mo	807	Tc	808	Ru	809	Rh	810	Pd	811	Ag	812	Cd	813	In	814	Sn	815	Sb	816	Te	817	I	818	Xe	819	At	820	Rn	821	Fr	822	Ra	823	Ac	824	Th	825	Pa	826	U	827	Np	828	Pu	829	Am	830	Cm	831	Bk	832	Cf	833	Es	834	Fm	835	Mn	836	Fe	837	Co	838	Ni	839	Cu	840	Zn	841	Ga	842	Ge	843	As	844	Se	845	Br	846	Kr	847	Rb	848	Sr	849	Y	850	Zr	851	Nb	852	Mo	853	Tc	854	Ru	855	Rh	856	Pd	857	Ag	858	Cd	859	In	860	Sn	861	Sb	862	Te	863	I	864	Xe	865	At	866	Rn	867	Fr	868	Ra	869	Ac	870	Th	871	Pa	872	U	873	Np	874	Pu	875	Am	876	Cm	877	Bk	878	Cf	879	Es	880	Fm	881	Mn	882	Fe	883	Co	884	Ni	885	Cu	886	Zn	887	Ga	888	Ge	889	As	890	Se	891	Br	892	Kr	893	Rb	894	Sr	895	Y	896	Zr



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**CHEMISTRY****9701/35**

Paper 3 Advanced Practical Skills 1

October/November 2024**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 The neutralisation of an acid by an alkali is an exothermic reaction. The concentration of an acid can be found by measuring the temperature change when the acid reacts with an alkali.

You will determine the concentration of sulfuric acid by adding aqueous sodium hydroxide of known concentration to the sulfuric acid and measuring the temperature change.

FA 1 is 2.01 mol dm^{-3} sodium hydroxide, NaOH.

FA 2 is sulfuric acid, H_2SO_4 .

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Pipette 25.0 cm^3 of **FA 1** into the cup.
- Place the thermometer into the **FA 1** in the cup. Tilt the cup if necessary to ensure the bulb of the thermometer is fully covered. Record the temperature of **FA 1** in Table 1.1. This is the temperature when the volume of **FA 2** is 0.00 cm^3 .
- Fill the burette with **FA 2**.
- Run 5.00 cm^3 of **FA 2** into the cup containing **FA 1**.
- Stir the mixture and record the maximum temperature in Table 1.1.
- Run further 5.00 cm^3 portions of **FA 2** into the same cup.
- After each addition of **FA 2** stir the contents of the cup. Record the maximum temperature for each addition.

Table 1.1

total volume of FA 2 / cm^3	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
temperature / $^{\circ}\text{C}$									

I	
II	
III	
IV	

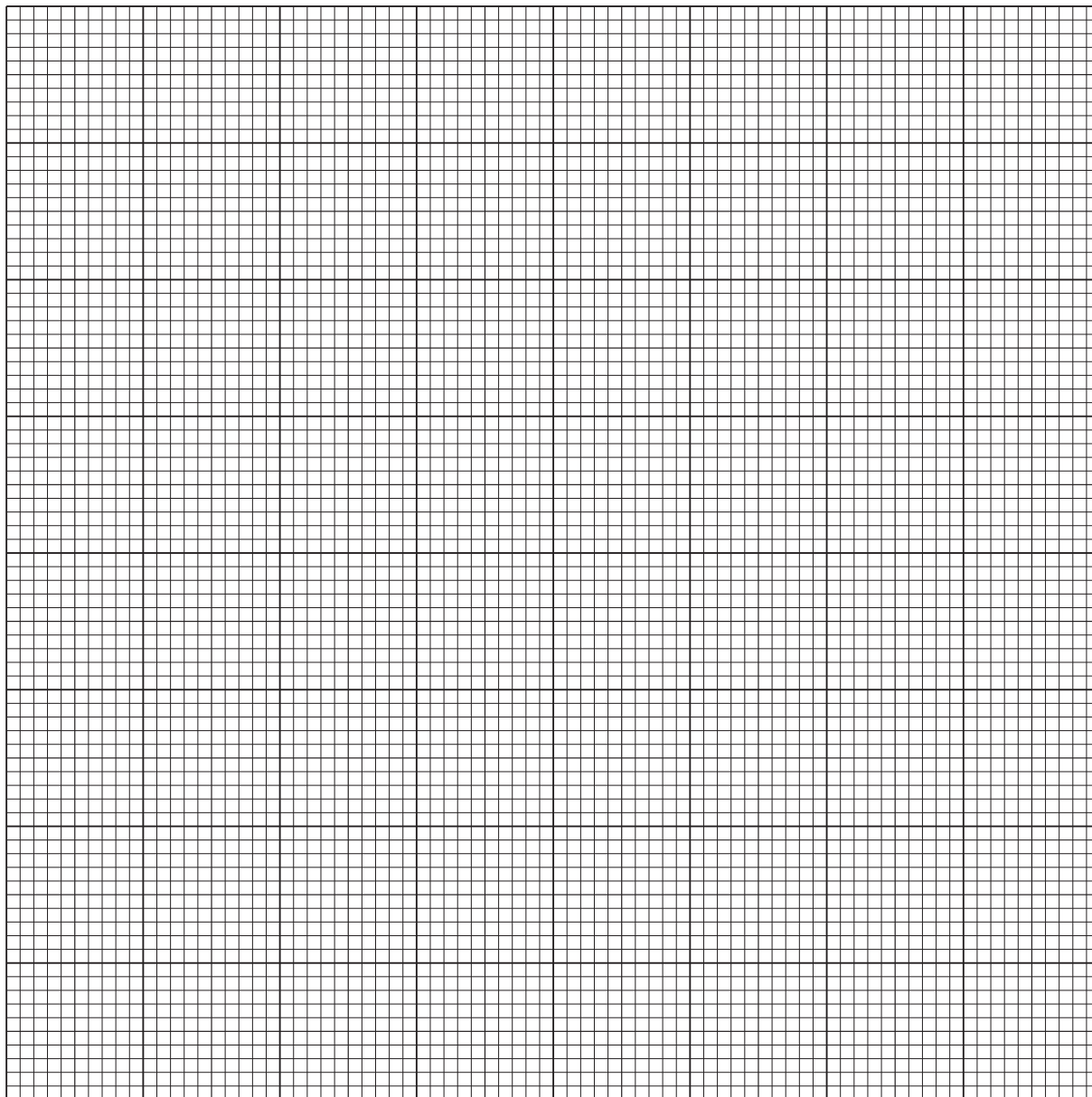
[4]

Keep the rest of **FA 2** for use in Question 2.



- (b) Plot a graph of temperature of solution (y-axis) against total volume of **FA 2** added (x-axis) on the grid. Select a scale for the y-axis to include a value 3°C above your maximum temperature reading. Label any points you consider to be anomalous.

Draw **two** lines of best fit through the points on your graph. Draw the first line for the increase in temperature and the second line after the maximum temperature was reached. Extrapolate the lines so they intersect. This intersection corresponds to the volume of **FA 2** needed to neutralise the **FA 1** in your experiment in (a).



I	
II	
III	
IV	
V	

25.0 cm³ of **FA 1** required cm³ of **FA 2**.

[5]

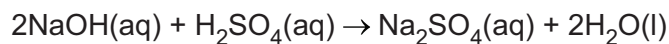




(c) (i) Calculate the amount, in mol, of sodium hydroxide, **FA 1**, pipetted into the cup.

amount of NaOH = ... mol [1]

(ii) The equation for this neutralisation reaction is shown.



Calculate the concentration, in mol dm^{-3} , of sulfuric acid in **FA 2**.

Show your working.

concentration of H_2SO_4 = ... mol dm^{-3}
[2]

[Total: 12]





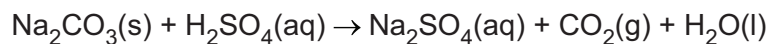
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2 Acids react with carbonates to produce carbon dioxide gas.



This reaction can be used to determine the concentration of acid, using the mass of carbon dioxide released.

You will determine the concentration of sulfuric acid in **FA 2**.

FA 2 is the solution used in **Question 1**.

FA 3 is sodium carbonate, Na_2CO_3 .

(a) Method

- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 2** into the conical flask.
- Weigh the flask with the acid. Record the mass.
- Weigh the container with **FA 3**. Record the mass.
- Carefully tip all of **FA 3** into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand with occasional swirling until the fizzing stops.
- Weigh the container with any residual **FA 3**. Record the mass.
- Calculate and record the mass of **FA 3** added to the flask.
- Calculate and record the total mass of flask + acid + **FA 3**.
- Weigh the flask and contents when the fizzing has stopped. Record the mass.
- Calculate and record the mass of carbon dioxide given off during the experiment.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

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

amount of CO_2 = ... mol [1]





- (ii) The sodium carbonate, **FA 3**, was in excess in the reaction with sulfuric acid. Show by calculation that the sodium carbonate was in excess. Use your answer to **(b)(i)**.

[2]

- (iii) Calculate the concentration, in mol dm^{-3} , of sulfuric acid in **FA 2**.

concentration of H_2SO_4 = ... mol dm^{-3} [1]

- (c) (i) A student does not have a conical flask and uses a small beaker for the reaction. Explain why a conical flask is better.

.....

..... [1]

- (ii) Two students made suggestions of how they thought the experiment in **(a)** could be adapted to determine the concentration of sulfuric acid, **FA 2**, by using other reactions. In each case their teacher told them that this method was not suitable.

Explain, in each case, why the method is **not** suitable. Do **not** consider factors based on quantities of any reagent.

Student 1 suggested using magnesium in place of sodium carbonate.

.....

.....

Student 2 suggested using calcium carbonate in place of sodium carbonate.

.....

.....

[3]





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

uncertainty = $\pm$ g

Calculate the maximum percentage error in the mass of **FA 3** that you weighed out in (a).

maximum percentage error = ... % [1]

[Total: 14]

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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. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

3 FA 4, FA 5 and FA 6 are compounds of the same metal in different oxidation states.

- (a) (i) Place a small spatula measure of **FA 4** in a hard-glass test-tube. Heat the tube gently at first and then more strongly.

Record all your observations.

Leave the tube and contents to cool and keep for use in (a)(iii).

.....

.....

.....

..... [2]





- (ii) Dissolve a **small** spatula measure of **FA 4** in approximately 5 cm depth of distilled water in a boiling tube and add approximately 1 cm depth of dilute sulfuric acid.

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

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of aqueous FA 4 in a test-tube add aqueous iron(II) sulfate.	
Test 2 To a 1 cm depth of aqueous FA 4 in a test-tube add hydrogen peroxide.	

[2]

- (iii) To the cooled test-tube in (a)(i) add a 5 cm depth of distilled water. Observe and record the colour formed.

..... [1]



- (b) Dissolve a small spatula measure of **FA 5** in a boiling tube half-filled with distilled water. Warming may be needed to dissolve the **FA 5**.

Carry out the following tests and record your observations in Table 3.2.

For each of the tests use a 1 cm depth of this **FA 5** solution in a test-tube.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 Add dilute nitric acid, then	
add aqueous silver nitrate.	
Test 2 Add aqueous barium chloride or barium nitrate, then	
add dilute nitric acid.	
Test 3 Add aqueous sodium hydroxide, then	
add hydrogen peroxide.	

[3]





- (c) Carry out the following tests and record your observations in Table 3.3. Identify any gases produced.

For each of the tests use a small spatula measure of **FA 6** in a test-tube.

Table 3.3

<i>test</i>	<i>observations and gases produced</i>
Test 1 Add a 1 cm depth of dilute nitric acid.	
Test 2 Add a few drops of concentrated hydrochloric acid. CARE Hydrochloric acid is corrosive. Fill the test-tube with water as soon as you have made your observation.	
Test 3 Add a 1 cm depth of hydrogen peroxide.	

[3]

- (d) (i) Use your observations from the tests on **FA 4**, **FA 5** and **FA 6** to suggest the identity of the metal present in all 3 compounds.

Metal identity

[1]

- (ii) Identify the oxidation state of the metal in each compound.

FA 4

FA 5

FA 6

[2]

[Total: 14]





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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 $\text{J g}^{-1} \text{ K}^{-1}$)

Group																	
1	2	Key															
		atomic number atomic symbol name relative atomic mass															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Li lithium 6.9	Be beryllium 9.0	11	12									5	6	7	8	9	10
Na sodium 23.0	Mg magnesium 24.3											13	14	15	16	17	18
												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 —	At astatine —	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 —

57	La	lanthanum	138.9
58	Ce	cerium	140.1
59	Pr	praseodymium	140.9
60	Nd	neodymium	144.2
61	Pm	promethium	—
62	Sm	samarium	150.4
63	Eu	europtium	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	208.9
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	—

89	Th Ac actinium
90	Pa protactinium 231.0 232.0
91	U uranium 238.0
92	Np neptunium —
93	Pu plutonium —
94	Am americium —
95	Cm curium —
96	Bk berkelium —
97	Cf californium —
98	Es einsteinium —
99	Fm fermium —
100	Md mendelevium —
101	No nobelium —
102	Lr lawrencium —
103	



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CHEMISTRY

9701/36

Paper 3 Advanced Practical Skills 2

October/November 2024

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 accuracy 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 Sodium carbonate reacts with hydrochloric acid to release carbon dioxide as shown.



You will find the percentage purity in a sample of impure sodium carbonate by reacting it with excess hydrochloric acid and measuring the volume of carbon dioxide formed. You may assume that the impurity does not react with acid to produce a gas.

FB 1 is impure sodium carbonate, Na_2CO_3 .

FB 2 is hydrochloric acid, HCl .

(a) Method

- Weigh the container with **FB 1**. Record the mass.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm³ 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.
- Use the 50 cm³ measuring cylinder to transfer 50.0 cm³ of **FB 2** into the flask labelled **X**. Check the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the delivery tube into the inverted 250 cm³ measuring cylinder.
- Remove the bung from the neck of the flask. Tip all the **FB 1** 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 and leave until the fizzing has stopped.
- Remove the flask from the clamp occasionally, swirl it and replace the flask in the clamp.
- Weigh the empty container that held **FB 1**. Record the mass.
- Calculate and record the mass of **FB 1** added.
- When no more gas is collected, record the final volume of gas produced.

You may wish to start Question 2 while the gas is being produced.

Results

I	
II	
III	
IV	

[4]



**(b) Calculations**

- (i) Give your answers to each part of **(b)(ii)**, **(b)(iii)** and **(b)(iv)** to an appropriate number of significant figures.

[1]

- (ii) Calculate the amount, in mol, of carbon dioxide collected in the 250 cm³ measuring cylinder.

amount of CO₂ = ... mol [1]

- (iii) Use your answer to **(b)(ii)** to deduce the amount, in mol, of the sodium carbonate present in the **FB 1** you used in your experiment.

amount of Na₂CO₃ = ... mol

Use your answer to calculate the mass, in g, of sodium carbonate in your sample of **FB 1**.

mass of Na₂CO₃ = ... g
[1]

- (iv) Calculate the percentage purity of **FB 1**.

percentage purity = ... % [1]





- (c) Even though the bung was replaced quickly, some carbon dioxide was lost. Suggest a change you could make to minimise gas loss at this stage.

.....

 [1]

- (d) Some carbon dioxide is not collected because it is slightly soluble in water. State a change you could make to reduce the solubility of the gas.

Do not suggest using a liquid other than water in your tub or changing the volume of water used.

.....

 [1]

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

uncertainty = $\pm$ g

Calculate the maximum percentage error in the mass of **FB 1** used in (a).

maximum percentage error = ... %
 [1]

[Total: 11]



- 2 Many metal carbonates, such as magnesium carbonate, decompose to form the metal oxide when heated.



Other metal carbonates, such as sodium carbonate, Na_2CO_3 , do not decompose at the temperature produced by a Bunsen burner.

FB 3 is a mixture that contains only sodium carbonate, Na_2CO_3 , and magnesium carbonate.

You will carry out an experiment involving thermal decomposition to find the percentage of each of these metal carbonates in this mixture.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FB 3** from the container into the crucible.
- Weigh the crucible, lid and **FB 3**. Record the mass.
- Calculate and record the mass of **FB 3** used.
- Place the crucible and contents on the pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately 1 minute.
- Heat strongly, with the lid off, for a further 5 minutes.
- Leave the crucible with its contents until it is cool.

While the crucible is cooling, 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 the crucible strongly, with the lid off, for approximately 4 minutes.
- Allow the crucible and contents to cool.
- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of residue.
- Calculate and record the mass of carbon dioxide produced.

Leave the crucible and contents to become completely cool for use in Question 2(c).

Results

I	
II	
III	
IV	
V	

[5]



**(b) Calculations**

- (i) Calculate the amount, in mol, of carbon dioxide produced in the decomposition.

amount of CO_2 = ... mol [1]

- (ii) Calculate the mass of magnesium carbonate in **FB 3**.

mass of MgCO_3 = ... g [1]

- (iii) Calculate the percentages by mass of magnesium carbonate and sodium carbonate in **FB 3**.

percentage by mass of MgCO_3 = ... %

percentage by mass of Na_2CO_3 = ... %
[1]

- (c) (i) Add a few drops of water to the cool residue in the crucible.
Use universal indicator to test the pH of the solution formed.
Tick (✓) one box to show the direction of the temperature change.

pH = ...

temperature goes up

☐

temperature goes down

☐

[1]

- (ii) Use these observations and the information about the thermal decomposition of magnesium carbonate to write an equation for the reaction in (c)(i). Include state symbols and the sign of ΔH .

..... [2]

- (iii) Suggest how you would show that sodium carbonate had not decomposed during the reaction in (a). State the reagent(s) and observations.

Do not carry out your test.

.....

..... [2]

[Total: 13]





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. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

- 3 FB 4** is a mixture of two salts that each contain one cation and one anion.
All the ions present are in the Qualitative analysis notes.

- (a) Place a small spatula measure of **FB 4** into a hard-glass test-tube. Heat the tube gently at first and then more strongly.

Record all your observations and identify any gas given off.

.....

.....

.....

.....

..... [4]





(b) To a 5 cm depth of distilled water in a boiling tube, add a spatula measure of **FB 4**. Shake the tube to dissolve the **FB 4**.

(i) Carry out the following tests using a 1 cm depth of this **FB 4** solution in a test-tube for each test. Record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide, then	
transfer the mixture into a boiling tube, add a piece of aluminium foil and heat gently.	
Test 2 Add an equal volume of dilute nitric acid, then	
add a few drops of aqueous silver nitrate.	
Test 3 Add aqueous barium chloride or barium nitrate, then	
add dilute nitric acid.	
Test 4 Add aqueous sodium carbonate dropwise with shaking until in excess.	

[5]

(ii) Use your observations in Table 3.1 to identify two anions which **must** be present in **FB 4**.

..... [2]





- (iii) Carry out further tests to confirm or identify which two cations are present in **FB 4**. Record the reagents and conditions needed, your observations and your conclusions in a suitable table.

[5]

[Total: 16]





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										13	14	15	16	17	18		
		atomic number atomic symbol name relative atomic mass																	
		1 H hydrogen 1.0																	
3	4											5	6	7	8	9			
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	2 He helium 4.0		
11	12											13	14	15	16	17			
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 —	At astatine —	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 oganeson —	

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 144.2	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 —			

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