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9701/31

May/June 2023

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions
Insert (enclosed)

- 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.

- 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.
- The insert contains additional resources referred to in the questions.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

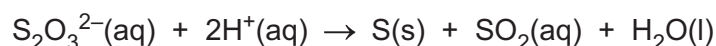
Quantitative Analysis

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

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

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

- 1 The thiosulfate ion, $\text{S}_2\text{O}_3^{2-}$, decomposes when an acid is added.



The rate of this reaction can be investigated by measuring how long it takes the solution to produce enough sulfur so that it cannot be seen through.

You will investigate how the concentration of the thiosulfate ion affects the rate of the reaction.

Note: A small amount of sulfur dioxide gas may be formed in the experiment. It is very important that you avoid inhaling any fumes. As soon as each experiment is complete, empty the reaction mixture into the quenching bath and rinse the beaker thoroughly.

FA 1 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

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

(a) Method

Experiment 1

- Fill a burette with **FA 1**.
- Run 40.00 cm^3 of **FA 1** into the 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 2**.
- Add the **FA 2** to the **FA 1** in the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above, through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second in the space for results on page 4.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker and glass rod so they are ready to use in Experiment 2.

Experiment 2

- Refill the burette with **FA 1**.
- Fill the other burette with distilled water.
- Run 20.00 cm³ of **FA 1** into the 100 cm³ beaker.
- Run 20.00 cm³ of distilled water into the same beaker.
- Use the 25 cm³ measuring cylinder to measure 10.0 cm³ of **FA 2**.
- Add the **FA 2** to the solution in the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above, through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker and glass rod so they are ready to use in the next experiment.

Experiments 3–5

- Carry out **three** further experiments to investigate how using different volumes of **FA 1** affects the reaction time.

Note that the combined volumes of **FA 1** and distilled water must always be 40.00 cm³.

Do **not** use a volume of **FA 1** that is less than 15.00 cm³.

Record all your results in a table. You should include the volume of **FA 1**, the volume of distilled water, the reaction time and the reaction rate for each of your five experiments.

The rate of reaction can be calculated using the following formula.

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

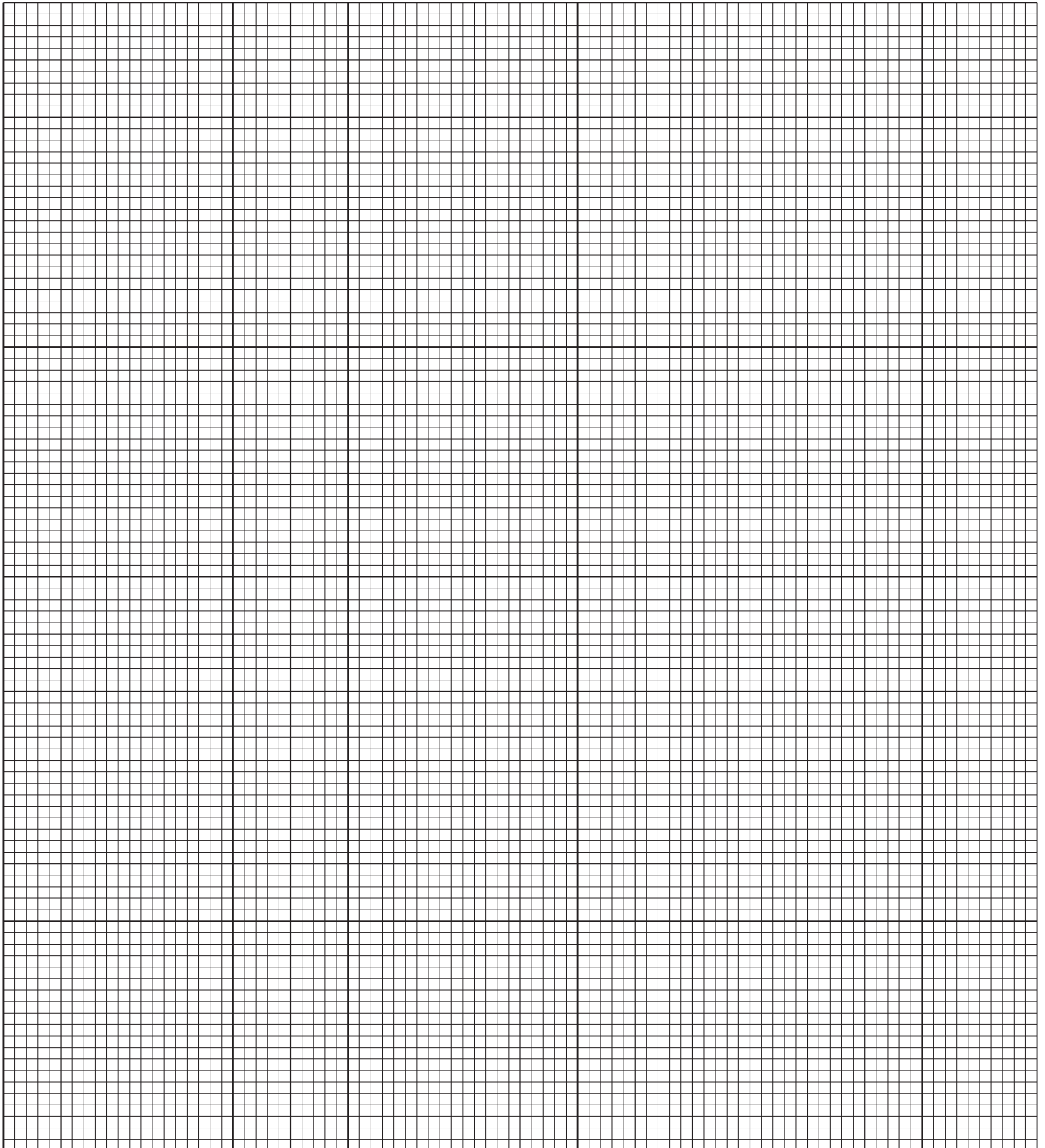
Results

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

- (b) On the grid, plot the rate (y -axis) against the volume of **FA 1** (x -axis).
Start each axis at the origin (0,0).

Ring any anomalous points. Draw a line of best fit.



I	
II	
III	
IV	

[4]

- (c) In these experiments, the volume of **FA 1** is a measure of the concentration of thiosulfate ions.

A student suggested that the graph shows that the rate of reaction is directly proportional to the concentration of thiosulfate ions.

Explain, using your graph, whether you agree with this student.

.....

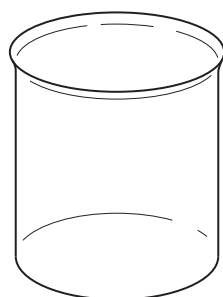
 [1]

- (d) Use your graph to calculate the time you would expect to record if you had used 12.50 cm^3 of **FA 1** and followed the same method.

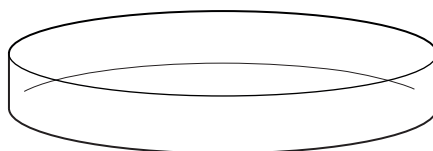
Show clearly on the graph how you calculated this time.

time = ... s [2]

- (e) Another student broke the beaker and decided to use a Petri dish instead.



beaker



Petri dish

Fig. 1.1

What effect, if any, would this have on the times measured in the experiment in (a)?
 Explain your answer.

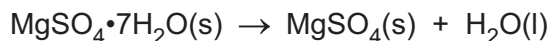
.....

 [2]

[Total: 17]

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- 2 Many salts contain water of crystallisation which can be removed by heating to form the anhydrous salt. You will determine the enthalpy change of dehydration for hydrated magnesium sulfate.



You will determine this enthalpy change by measuring the changes in temperature when samples of hydrated magnesium sulfate and anhydrous magnesium sulfate are dissolved separately in excess water.

FA 3 is hydrated magnesium sulfate, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.

FA 4 is anhydrous magnesium sulfate, MgSO_4 .

(a) Method

Experiment 1

- Weigh the container with **FA 3**. Record the mass in the space below.
- Support the cup in the 250 cm³ beaker.
- Rinse the 25 cm³ measuring cylinder with distilled water. Use the measuring cylinder to transfer 25.0 cm³ of distilled water into the cup.
- Place the thermometer in the water and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature.
- Tip all of the **FA 3** into the water in the cup. Stir the mixture thoroughly.
- Record the highest or lowest temperature of the mixture.
- Calculate the change in temperature. Record this change.
- Weigh the container with any remaining **FA 3**. Record the mass.
- Calculate the mass of **FA 3** used. Record this mass.

Experiment 2

- Repeat the method using **FA 4** in place of **FA 3**. Use the second cup.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Calculate the heat energy transferred, in J, in each experiment.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.

Experiment 1 with FA 3	Experiment 2 with FA 4
heat energy = ... J	heat energy = ... J

[1]

- (ii) Calculate the enthalpy change, ΔH , in kJ mol⁻¹, when 1.0 mol of solid dissolves in water in each experiment.

Experiment 1 with FA 3	Experiment 2 with FA 4
$\Delta H_1 = \underset{\text{sign}}{\text{.....}} \underset{\text{value}}{\text{.....}} \text{ kJ mol}^{-1}$	$\Delta H_2 = \underset{\text{sign}}{\text{.....}} \underset{\text{value}}{\text{.....}} \text{ kJ mol}^{-1}$

[3]

- (iii) Use your answers to (b)(ii) to calculate the enthalpy change when 1.0 mol of hydrated magnesium sulfate is dehydrated to form 1.0 mol of anhydrous magnesium sulfate.



Show clearly, by a Hess's energy cycle or any other suitable means, how you calculated your answer.

If you were unable to complete the calculation in (b)(ii) then assume that the enthalpy change in Experiment 1, ΔH_1 , is $+8.7 \text{ kJ mol}^{-1}$ and that the enthalpy change in Experiment 2, ΔH_2 , is $-15.5 \text{ kJ mol}^{-1}$. These may **not** be the correct values.

enthalpy change of dehydration of $\text{MgSO}_4 \cdot 7\text{H}_2\text{O} = \underset{\text{sign}}{\text{.....}} \underset{\text{value}}{\text{.....}} \text{ kJ mol}^{-1}$ [2]

[Total: 11]

Qualitative analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

- 3 (a) (i)** A student finds a container of a compound which is thought to be **FA 3**. The student labels the container **FA 5**.

Carry out tests to determine whether your sample of **FA 5** contains magnesium ions, sulfate ions and water of crystallisation.

Record your tests and observations in a suitable form in the space below.

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

[4]

- (ii) Complete Table 3.1 to indicate the contents of **FA 5**.
Put a tick (✓) in **one** box in each row.

Table 3.1

	yes	no
FA 5 contains magnesium ions		
FA 5 contains sulfate ions		
FA 5 contains water of crystallisation		

[1]

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

- (i) In a hard-glass test-tube heat a spatula measure of **FA 6**. Heat gently at first and then heat strongly. Record **all** your observations.

.....

.....

.....

.....

..... [2]

- (ii) Carry out the following tests and record your observations.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 To a small spatula measure of FA 6 in a test-tube, add 5 cm depth of dilute hydrochloric acid. Keep the solution for Test 2.	
Test 2 Put 1 cm depth of the solution from Test 1 in a test-tube. Add aqueous ammonia dropwise at first and then until it is in excess.	

[2]

- (iii) Use your observations from (b)(i) and (ii) to identify the ions present in **FA 6**.

cation anion [1]

- (iv) Write the **ionic** equation for the reaction that occurs in Test 2 before excess ammonia is added. Include state symbols.

If you were unable to identify the cation in the solution then use the symbol M^{2+} .

..... [2]

[Total: 12]

Qualitative analysis notes

1 Reactions of cations

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

2 Reactions of anions

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

3 Tests for gases

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

4 Tests for elements

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

Important values, constants and standards

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

The Periodic Table of Elements

Group																																
1	2	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	10	11	12							2
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																	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 —			

lanthanoids

actinoids

57	La	lanthanum	138.9
58	Ce	cerium	140.1
59	Pr	praseodymium	140.9
60	Nd	neodymium	144.4
61	Pm	promethium	—
62	Sm	samarium	150.4
63	Eu	europlum	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	209.0
85	At	astatine	210.0
86	Rn	radon	222.0
87	Fr	francium	223.0
88	Ra	radium	226.0
89	Ac	actinium	227.0
90	Th	thorium	232.0
91	Pa	protactinium	231.0
92	U	uranium	238.0
93	Np	neptunium	237.0
94	Pu	plutonium	244.0
95	Am	americium	243.0
96	Cm	curium	247.0
97	Bk	berkelium	247.0
98	Cf	californium	251.0
99	Es	einsteinium	252.0
100	Fm	fermium	257.0
101	Md	mendelevium	258.0
102	No	nobelium	259.0
103	Lr	lawrencium	262.0



Cambridge International AS & A Level

CANDIDATE
NAME

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NUMBER

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CHEMISTRY

9701/32

Paper 3 Advanced Practical Skills 2

May/June 2023

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

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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 In this experiment you will determine the relative atomic mass, A_r , of metal **M** by thermal decomposition of its basic carbonate, $\text{MCO}_3 \cdot \text{M}(\text{OH})_2$.

FB 1 is the basic metal carbonate, $\text{MCO}_3 \cdot \text{M}(\text{OH})_2$.

(a) Method

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

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

- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Place the crucible and contents on the pipe-clay triangle. Remove the lid.
- Heat the crucible strongly for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible is cool, 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) Calculations

- (i) When **FB 1** undergoes thermal decomposition, the products are the metal oxide, **MO**, carbon dioxide and water vapour.
Give the equation for the thermal decomposition of **FB 1**. Include state symbols.

..... [1]

- (ii) The amount, in mol, of carbon dioxide produced is given by the following formula.

$$\text{amount of CO}_2 = \frac{\text{mass loss during heating}}{(M_r \text{ of CO}_2 + M_r \text{ of water})}$$

Calculate the amount, in mol, of carbon dioxide produced in (a).

amount of CO₂ = ... mol [1]

- (iii) Calculate the relative formula mass, M_r , of the basic metal carbonate.
Show your working.

M_r of $\text{MCO}_3 \cdot \text{M(OH)}_2$ = ... [1]

- (iv) Calculate the relative atomic mass of metal **M**.

A_r of **M** = ... [1]

- (c) A student accidentally spilt a little of the residue before carrying out the final weighing.
Predict whether the calculated value of the relative atomic mass of **M** will be higher or lower
as a result of this mistake.
Explain your answer.

The A_r of **M** will be

explanation

.....

..... [1]

- (d) A student suggested that addition of sulfuric acid to the residue from (a) would show whether
the basic metal carbonate had decomposed fully.
State whether the student is correct.
Explain your answer.

.....

.....

..... [1]

[Total: 11]

- 2 In this experiment you will determine the relative atomic mass, A_r , of another metal, **X**, by a titration method using the metal carbonate, X_2CO_3 .

FB 2 is $0.0460 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FB 3 is the metal carbonate, X_2CO_3 .

FB 4 is methyl orange indicator.

(a) **Method**

Preparing a solution of FB 3

- Weigh the stoppered container of **FB 3**. Record the mass in the space below.
- Tip all of the **FB 3** into the 250 cm^3 beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FB 3** used.
- Add approximately 100 cm^3 of distilled water to **FB 3** in the beaker.
- Stir the mixture with a glass rod until all the **FB 3** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of X_2CO_3 is **FB 5**. Label the flask **FB 5**.

Titration

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 5** into a conical flask.
- Add several drops of **FB 4** to the 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, in a suitable form below, all of your burette readings and the volume of **FB 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

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

25.0 cm³ of **FB 5** required cm³ of **FB 2**. [1]

(c) Calculations

- (i) Give your answers to **(c)(ii)**, **(c)(iv)**, **(c)(v)** and **(c)(vi)** to an appropriate number of significant figures. [1]
- (ii) Calculate the amount, in mol, of hydrochloric acid present in the volume of **FB 2** in **(b)**.

amount of HCl = ... mol [1]

- (iii) Give the ionic equation for the reaction of hydrochloric acid with the metal carbonate during the titration. Include state symbols.

.....CO₃²⁻..... + ... → + ... [1]

- (iv) Calculate the concentration of **X₂CO₃**, in mol dm⁻³, in **FB 5**.

concentration of **X₂CO₃** in **FB 5** = ... mol dm⁻³ [1]

(v) Calculate the relative formula mass, M_r , of X_2CO_3 .

M_r of X_2CO_3 = ... [1]

(vi) Calculate the relative atomic mass of **X**.

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

(vii) Identify **X**.

X is [1]

[Total: 16]

Qualitative Analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

- 3 (a) FB 6** is a solution containing one cation listed in the Qualitative analysis notes.
The anion contains sulfur.

- (i) State the reagents you would use to identify the cation in **FB 6**.

reagents

Use your selected reagents to test **FB 6**.

Use 1 cm depth of **FB 6** in a test-tube for each test.

Record your observations in the space below.

[2]

- (ii) Identify the anion in **FB 6**.
Include a description of your procedure and the observations you make.

anion in **FB 6** [2]

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

formula of **FB 6** [1]

- (b) You will devise chemical tests to distinguish between the two possible identities given for each of compounds **FB 7**, **FB 8**, **FB 9** and **FB 10**.

In each case, you should:

- name the reagent or reagents you will use to identify the compound
- state any necessary conditions for your test
- use a 1 cm depth of the solution of the unknown compound and use a boiling tube if you need to warm a mixture
- carry out your test and record the observations you make (if any)
- state your conclusion about the identity of the compound.

- (i) **FB 7** is either aqueous sodium nitrate or aqueous sodium nitrite.

FB 7 is [2]

- (ii) **FB 8** is either aqueous sodium nitrate or aqueous silver nitrate.

FB 8 is [2]

- (iii) **FB 9** is either aqueous ethanol or aqueous propan-1-ol.
(In your test, do **not** heat but you may need to leave your reaction mixture to stand.)

FB 9 is [2]

- (iv) **FB 10** is either aqueous methanol or aqueous ethanoic acid.

FB 10 is [2]

[Total: 13]

Qualitative analysis notes

1 Reactions of cations

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

2 Reactions of anions

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

3 Tests for gases

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

4 Tests for elements

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

Important values, constants and standards

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

The Periodic Table of Elements

Group																		
1	2	Key														18		
		1 H hydrogen 1.0																
		atomic number atomic symbol name relative atomic mass																
3	4																	
Li lithium 6.9	Be beryllium 9.0																	
11	12																	
Na sodium 23.0	Mg magnesium 24.3																	
19	20																	
K potassium 39.1	Ca calcium 40.1																	
37	38																	
Rb rubidium 85.5	Sr strontium 87.6																	
55	56																	
Cs caesium 132.9	Ba barium 137.3																	
87	88																	
Fr francium —	Ra radium —																	

lanthanoids

actinoids

57	La	lanthanum	138.9
58	Ce	cerium	140.1
59	Pr	praseodymium	140.9
60	Nd	neodymium	144.4
61	Pm	promethium	—
62	Sm	samarium	150.4
63	Eu	euroium	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	209.0
85	At	astatine	210.0
86	Rn	radon	222.0
87	Fr	francium	223.0
88	Ra	radium	226.0
89	Ac	actinium	227.0
90	Th	thorium	232.0
91	Pa	protactinium	231.0
92	U	uranium	238.0
93	Np	neptunium	237.0
94	Pu	plutonium	244.1
95	Am	americium	243.1
96	Cm	curium	247.1
97	Bk	berkelium	247.1
98	Cf	californium	251.1
99	Es	einsteinium	252.1
100	Fm	fermium	257.1
101	Md	mendeleevium	258.1
102	No	nobelium	259.1
103	Lr	lawrencium	262.1



* 0 7 1 0 6 5 7 8 5 7 *

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9701/33

May/June 2023

2 hours

You will need: The materials and apparatus listed in the confidential instructions
Insert (enclosed)

- 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.

- 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.
- The insert contains additional resources referred to in the questions.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages.

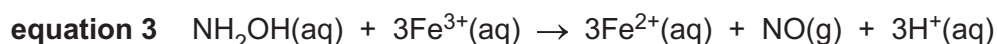
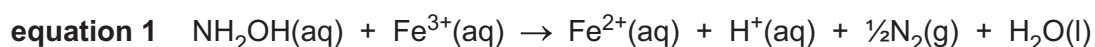
Quantitative Analysis

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

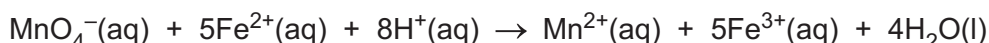
Show the precision of the apparatus you used in the data you record.

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

- 1** A redox reaction takes place between hydroxylamine, NH_2OH , and the iron(III) ion, Fe^{3+} , in acidic conditions. The iron(III) ion is reduced to an iron(II) ion, Fe^{2+} . The reaction is slow at room temperature but is complete in a few minutes at 100°C . The reaction is shown by one of the following equations.



You will carry out a titration to determine which of equations 1, 2 or 3 best represents the reaction. The iron(II) ions formed in the reaction with the hydroxylamine are oxidised by manganate(VII) ions.



FA 1 is $0.0200\text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 2 is a solution prepared by boiling a 1.00 dm^3 aqueous mixture containing 3.30 g of hydroxylamine hydrochloride, $\text{NH}_2\text{OH}\cdot\text{HCl}$, excess iron(III) chloride, FeCl_3 , and excess sulfuric acid. Any water lost by evaporation was replaced after cooling.

FA 3 is dilute sulfuric acid.

Assume that one mole of hydroxylamine hydrochloride gives one mole of hydroxylamine in solution.

(a) Method

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 2** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 of **FA 3** 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, in a suitable form, all your burette readings and the volume of **FA 1** added in each accurate titration.

Keep FA 3 for use in Question 2(a).

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

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

(c) Calculations

- (i) Calculate the amount, in mol, of potassium manganate(VII) present in the volume of **FA 1** in (b).

amount of KMnO₄ = ... mol [1]

- (ii) Use your answer to (c)(i) to calculate the amount, in mol, of iron(II) ions in 25.0 cm³ of solution **FA 2**.

amount of Fe²⁺ = ... mol [1]

- (iii) Calculate the amount, in mol, of hydroxylamine hydrochloride that has reacted in the **FA 2** pipetted into the conical flask. Show your working.

amount of NH₂OH·HCl = ... mol [2]

- (iv) Use your answer to (c)(iii) to deduce which of the three suggested equations corresponds to your results. Show your working.

The correct equation number is [1]

[Total: 13]

[Turn over]

- 2 The reaction between thiosulfate ions and hydrogen ions produces a precipitate of sulfur. When the concentration of hydrogen ions, $[H^+(aq)]$, is kept constant, the rate is proportional to one of the following:

- the concentration of thiosulfate ions, $[S_2O_3^{2-}(aq)]$
- the square of the concentration of thiosulfate ions, $[S_2O_3^{2-}(aq)]^2$.

You will determine which relationship is correct by mixing solutions of sodium thiosulfate and sulfuric acid. You will measure the time taken for a fixed amount of sulfur to be precipitated.

Throughout these experiments care must be taken to avoid inhaling any SO_2 gas that is produced. It is very important that as soon as each experiment is complete, the contents of the beaker are emptied into the quenching bath and the beaker is rinsed thoroughly.

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

FA 4 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $Na_2S_2O_3$.

(a) Method

Experiment 1

- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 4** into the 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 3**.
- Add **FA 3** to **FA 4** in the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above, through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second in Table 2.1.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker and glass rod so they are ready for use in Experiment 2.

Experiment 2

- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of **FA 4** into the 100 cm^3 beaker.
- Use the same measuring cylinder to add 20.0 cm^3 of distilled water to the same beaker.
- Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 3**.
- Add **FA 3** to the mixture of **FA 4** and distilled water in the beaker and start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above, through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second in Table 2.1.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker and glass rod so they are ready for use in Experiment 3.

Experiment 3

- Carry out **one** further experiment to investigate how the reaction time changes with a different volume of **FA 4**.

Do **not** use a volume of **FA 4** that is less than 20.0 cm^3 .

Record your results in Table 2.1.

Results

Table 2.1

experiment	volume / cm ³			reaction time / s
	FA 3	FA 4	distilled water	
1	10.0	50.0	0	
2	10.0	30.0	20.0	
3				

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Complete Table 2.2. Use the following expression to calculate the rate.

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

Table 2.2

experiment	concentration of FA 4 / mol dm ⁻³	rate / s ⁻¹
1		
2		
3		

[2]

- (ii) Use data from two of your experiments to deduce which relationship for the rate is correct. Place a tick next to the statement in Table 2.3 which most accurately fits your results.
Show your working.

Table 2.3

The rate is proportional to [S ₂ O ₃ ²⁻ (aq)].	
The rate is proportional to [S ₂ O ₃ ²⁻ (aq)] ² .	

[2]

- (c) The uncertainty in a 50 cm^3 measuring cylinder is $\pm 0.5\text{ cm}^3$.

Calculate the maximum percentage error in the volume of **FA 4** in Experiment 2.

maximum percentage error in volume of **FA 4** = ...% [1]

- (d) Suggest improvements to your method and the processing of the results that would allow you to make a more reliable conclusion in **(b)(ii)**.

Do **not** suggest changes to the apparatus or to the concentrations of **FA 3** and **FA 4**.

Do **not** carry out any of your suggestions.

.....

.....

.....

.....

..... [3]

[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 5 is a solid mixture of two salts and contains two different anions. None of the ions present contains nitrogen.

- (a) (i)** Place a small spatula measure of **FA 5** in a hard-glass test-tube. Heat the test-tube, gently at first, then more strongly, for a total of approximately 2 minutes. Then allow the test-tube to cool.
Record your observations.

.....

 [2]

- (ii)** Place a large spatula measure of **FA 5** in a boiling tube. Add an approximately 3 cm depth of distilled water and shake the tube and contents. Record your observations.

Keep the contents of the test-tube for use in (a)(iii).

.....

 [2]

- (iii)** Put 1 cm depth of the solution from **(a)(ii)** in a test-tube. Add aqueous sodium hydroxide. Record your observations.

..... [1]

- (b) (i) Put 3 cm depth of dilute nitric acid in a test-tube. Carefully add a spatula measure of **FA 5**. Record your observations.

Keep the contents of the test-tube for use in (b)(iii).

.....

 [2]

- (ii) Suggest what your observations in (a)(ii) tell you about the identity of one of the cations in **FA 5**.

..... [1]

- (iii) Select reagents for further tests to identify any anion present in **FA 5**.
 Carry out your tests and record your reagents, conditions and observations in the space below.

[2]

- (iv) From your observations in (b)(i) and (b)(iii), deduce the formulae of the two anions present in **FA 5**.

anions		
--------	--	--

[1]

- (v) Write an ionic equation for one reaction occurring in (b)(i) or (b)(iii).
 Include state symbols.

..... [1]

- (c) **FA 6** is a solution of a salt. One of the two ions contains a nitrogen atom. Both ions are listed in the Qualitative analysis notes.

Select reagents to identify the ion containing the nitrogen atom. Use a 1 cm depth of **FA 6** in a boiling tube to carry out your tests. Record your tests, results and conclusion in the space below.

[3]

[Total: 15]

Qualitative analysis notes

1 Reactions of cations

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

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
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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
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4 Tests for elements

element	test and test result
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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																		
		Key																
		atomic number atomic symbol name relative atomic mass										1 H hydrogen 1.0						
1	2											13	14	15	16	17	18	
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	2 He helium 4.0	
11	12											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	
19	20	3 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							
37	38	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	56	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	88	89–103 actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —

lanthanoids

actinoids

57	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	euroium	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	yterbium	173.1
71	Lu	lutetium	175.0



Cambridge International AS & A Level

CANDIDATE
NAME

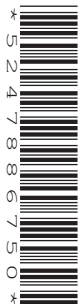
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CANDIDATE
NUMBER

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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

May/June 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.
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- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

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.

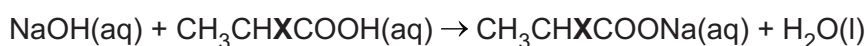
Quantitative analysis

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 investigate the enthalpy change of neutralisation, ΔH_{neut} , between aqueous sodium hydroxide of known concentration and a dilute organic acid. You will use your results to suggest the identity of the organic acid. The acid is a halogenocarboxylic acid containing one halogen atom, **X**, per molecule.



FB 1 is 1.90 mol dm^{-3} sodium hydroxide, NaOH.

FB 2 is a solution containing 312.5 g dm^{-3} of the organic acid $\text{CH}_3\text{CHXCOOH}$.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Pipette 25.0 cm^3 of **FB 1** into the cup.
- Place the thermometer into **FB 1**. Record the temperature of **FB 1** in Table 1.1. This is the temperature when the volume of **FB 2** is 0.00 cm^3 .
- Fill the burette with **FB 2**.
- Run 5.00 cm^3 of **FB 2** into the cup containing **FB 1**.
- Stir the mixture. Record the highest temperature observed.
- Run further 5.00 cm^3 portions of **FB 2** into the same cup.
- On each addition of **FB 2** stir the contents of the cup. Record the highest temperature after each addition.

I	
II	
III	

Results

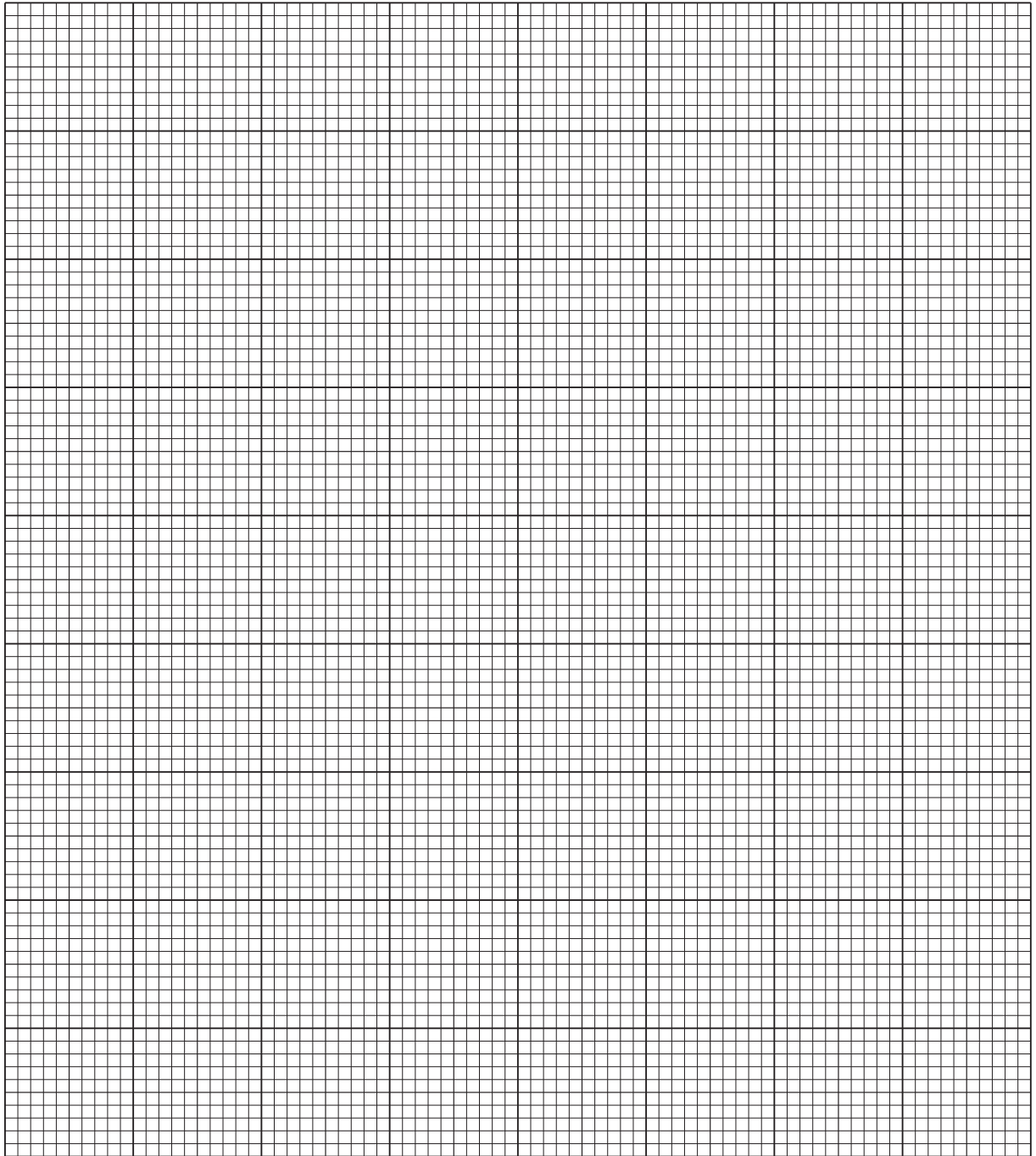
Table 1.1

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

[3]

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

Draw two lines of best fit, the first for the increase in temperature and the second for after the maximum temperature has been reached. Extrapolate the two lines so they intersect. This intersection corresponds to the volume of **FB 2** required to form a neutral solution.



I	
II	
III	
IV	

[4]

(ii) Use your graph to determine the volume of **FB 2** required to neutralise 25.0 cm³ of **FB 1**.

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

(c) Calculations

- (i) Calculate the energy change, in J, when the volume of **FB 2** recorded in **(b)(ii)** neutralises 25.0 cm³ of **FB 1**.

energy change = ... J [1]

- (ii) Calculate the amount, in mol, of sodium hydroxide, **FB 1**, pipetted into the cup.

amount of NaOH = ... mol [1]

- (iii) Calculate the enthalpy change of neutralisation, ΔH_{neut} , in kJ mol⁻¹, for 1.00 mol of sodium hydroxide reacting with **FB 2**.

ΔH_{neut} = $\frac{\text{.....}}{\text{sign}}$ $\frac{\text{.....}}{\text{value}}$ kJ mol⁻¹ [1]

- (iv) Use your answers to **(b)(ii)** and **(c)(ii)** and the information given on page 2 to calculate the relative formula mass, M_r , of the organic acid CH₃CHXCOOH. Show your working.

M_r of CH₃CHXCOOH = ... [1]

- (v) The acid is known to be one of the following: CH₃CHFCOOH, CH₃CHClCOOH, CH₃CHBrCOOH or CH₃CHICOOH. Use your answer to **(c)(iv)** to identify the acid used to make solution **FB 2**.

The acid in **FB 2** is [1]

- (vi) Calculate the percentage error in the relative formula mass, M_r , you calculated in **(c)(iv)**.

percentage error in M_r = ... % [1]

[Total: 14]

- 2 A gravimetric procedure can identify the metal in many metal carbonates. You will decompose a metal carbonate, MCO_3 , by heating to produce the metal oxide and carbon dioxide. You may assume this metal forms a stable metal oxide on heating. **M** is **not** a transition metal.



FB 3 is the metal carbonate MCO_3 .

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Add between 0.90 g and 1.10 g of **FB 3** to the crucible.
- Weigh the crucible, lid and **FB 3**. Record the mass.
- Place the crucible on the pipe-clay triangle.
- Gently heat the crucible and contents for approximately 1 minute with the lid on.
- Remove the lid. Then heat the crucible and contents strongly for approximately 5 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 is cool, weigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of **FB 3** added to the crucible, the mass of residue obtained and the mass loss.

Keep the residue for use in 2(d).

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Calculate the amount, in mol, of carbon dioxide lost on heating **FB 3**.

amount of CO_2 = ... mol [1]

- (ii) Use your answer to **(b)(i)** and your data from **(a)** to calculate the relative formula mass, M_r , of MCO_3 .

M_r of MCO_3 = ... [1]

- (iii) Use your answer to **(b)(ii)** to suggest the identity of metal **M**.
Show your working.

M is [1]

- (c) A student carrying out the same experiment as in **(a)** spills a small quantity of solid just before carrying out the final weighing.
State what effect this would have on the value of the M_r that is calculated for MCO_3 .
Explain your answer.

.....

 [1]

- (d) Normally, in this experiment, you would reheat and reweigh the crucible and contents until the mass is constant to ensure all the metal carbonate has decomposed.
Suggest a **chemical** test to determine whether all the metal carbonate has decomposed.

Record your test, observation and conclusion.

test
 observation
 conclusion
 [2]

[Total: 11]

Qualitative analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

- 3 Half fill the 250cm³ beaker with water and place it on a gauze on the tripod. Heat the water until boiling then switch off your Bunsen burner. This will be your hot water bath.

(a) **FB 4**, **FB 5** and **FB 6** are acids with the same concentration. Only one is an organic acid.

- (i) Carry out the following tests and record your observations in Table 3.1.
Use a 1 cm depth of **FB 4**, **FB 5** or **FB 6** in a test-tube for each test.

Table 3.1

<i>test</i>	<i>observations</i>		
	FB 4	FB 5	FB 6
Test 1 Add 1 or 2 drops of acidified aqueous potassium manganate(VII), then			
place the test-tube in the hot water bath.			
Test 2 Add a few copper turnings and place the test-tube in the hot water bath for a few minutes.			
Test 3 Add a 1 cm strip of magnesium ribbon, then			
leave the test-tube for 3 minutes and then shake the test-tube gently.			
At the end of the experiments rinse the test-tubes thoroughly.			

[7]

- (ii) Each of **FB 4**, **FB 5** and **FB 6** is one of the following acids: methanoic acid, nitric acid or sulfuric acid.

Use your observations to suggest the identity of each acid. Explain your answers.

FB 4 is

explanation

.....

FB 5 is

explanation

.....

FB 6 is

explanation

.....

[3]

- (b) The halogenocarboxylic acid in **FB 2** was hydrolysed by heating with excess aqueous sodium hydroxide. The resulting solution is **FB 7**.

- (i) Carry out a test to check the identity of the halogen atom present in **FB 2**.
Use a 1 cm depth of **FB 7** in a test-tube for your test.
State your reagents and record your observations at each stage of your test.

From this test **only**, give the identity of the halogen present in **FB 2**.

The halogen is [3]

- (ii) Give the equation for the hydrolysis reaction of the halogenocarboxylic acid, **FB 2**, with excess hot aqueous sodium hydroxide.
(If you were unable to identify the halogen in (b)(i), then use the formula $\text{CH}_3\text{CHXCOOH}$.)

..... [2]

[Total: 15]

Qualitative analysis notes

1 Reactions of cations

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

2 Reactions of anions

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

3 Tests for gases

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

4 Tests for elements

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

Important values, constants and standards

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

The Periodic Table of Elements

Group																						
1	2													13	14	15	16	17	18			
														1 H hydrogen 1.0								2 He helium 4.0

lanthanoids

actinoids

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



Cambridge International AS & A Level

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NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

May/June 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

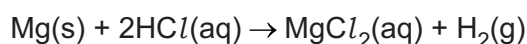
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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 Magnesium is a reactive metal which corrodes when left in air. Magnesium reacts with acid to release hydrogen.

You will determine the percentage purity of a sample of magnesium by reacting it with excess hydrochloric acid and measuring the volume of hydrogen formed.



FA 1 is hydrochloric acid, HCl .

FA 2 is magnesium, Mg .

(a) 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 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 **FA 1** into the flask labelled **X**. Check that the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm³ measuring cylinder.
- Remove the bung from the neck of the flask. Add all the **FA 2** to the acid and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp. Leave for several minutes, swirling the flask occasionally.
- Weigh the empty container. Record the mass.
- Calculate and record the mass of **FA 2** that is added to the acid.

Start Question 2 or Question 3 while the gas is being collected.

- When the reaction stops producing gas, record the final volume of gas collected.

I	
II	
III	

volume of gas = ... cm³ [3]

(b) Calculations

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

amount of H_2 = ... mol [1]

- (ii) Use your answer to **(b)(i)** to deduce the amount, in mol, of magnesium that reacted in your experiment.

amount of Mg = ... mol

Hence calculate the percentage purity of the magnesium.

purity of Mg = ... %
[2]

- (c) A student carries out this practical procedure but uses magnesium powder rather than magnesium ribbon. State the effect this would have on the percentage purity the student calculates. Explain your answer.

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

- (d) Another student investigates the reaction of a metal carbonate with hydrochloric acid by measuring the change in mass during the reaction. The reaction is carried out in a beaker on the pan of a balance.

- (i) Explain why the mass displayed on the balance decreases during the reaction.

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

- (ii) Explain why using a balance to monitor the reaction between magnesium and hydrochloric acid is **not** accurate.

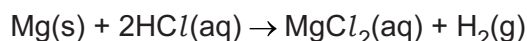
.....
.....
..... [2]

- (iii) Give the ionic equation for a solid carbonate, $\text{CO}_3^{2-}(\text{s})$, reacting with hydrochloric acid. Include state symbols.

..... [1]

[Total: 12]

- 2 In **Question 1** you determined the percentage purity of a sample of magnesium by measuring the volume of the gas produced when it reacts with an acid. In **Question 2** you will use the enthalpy change of the reaction between magnesium and hydrochloric acid to find the percentage purity. This reaction is exothermic.



FA 3 is hydrochloric acid, HCl . This is used in excess.

FA 4 is magnesium, Mg . You should assume it has a mass of 0.40 g.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Rinse the 50 cm^3 measuring cylinder with a little **FA 3**.
- Use the 50 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 3** into the cup.
- Place the thermometer in the acid and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Measure and record the temperature at time 0 minutes in Table 2.1.
- Start timing and do not stop the clock until the whole experiment has been completed at time 7 minutes.
- Record the temperature of **FA 3** in the cup every $\frac{1}{2}$ minute for $1\frac{1}{2}$ minutes.
- At time 2 minutes place **FA 4** into the acid and stir the mixture.
- Record the temperature every $\frac{1}{2}$ minute. Stir the mixture between thermometer readings.

Results

Table 2.1

time / minutes	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$
temperature / °C					X			

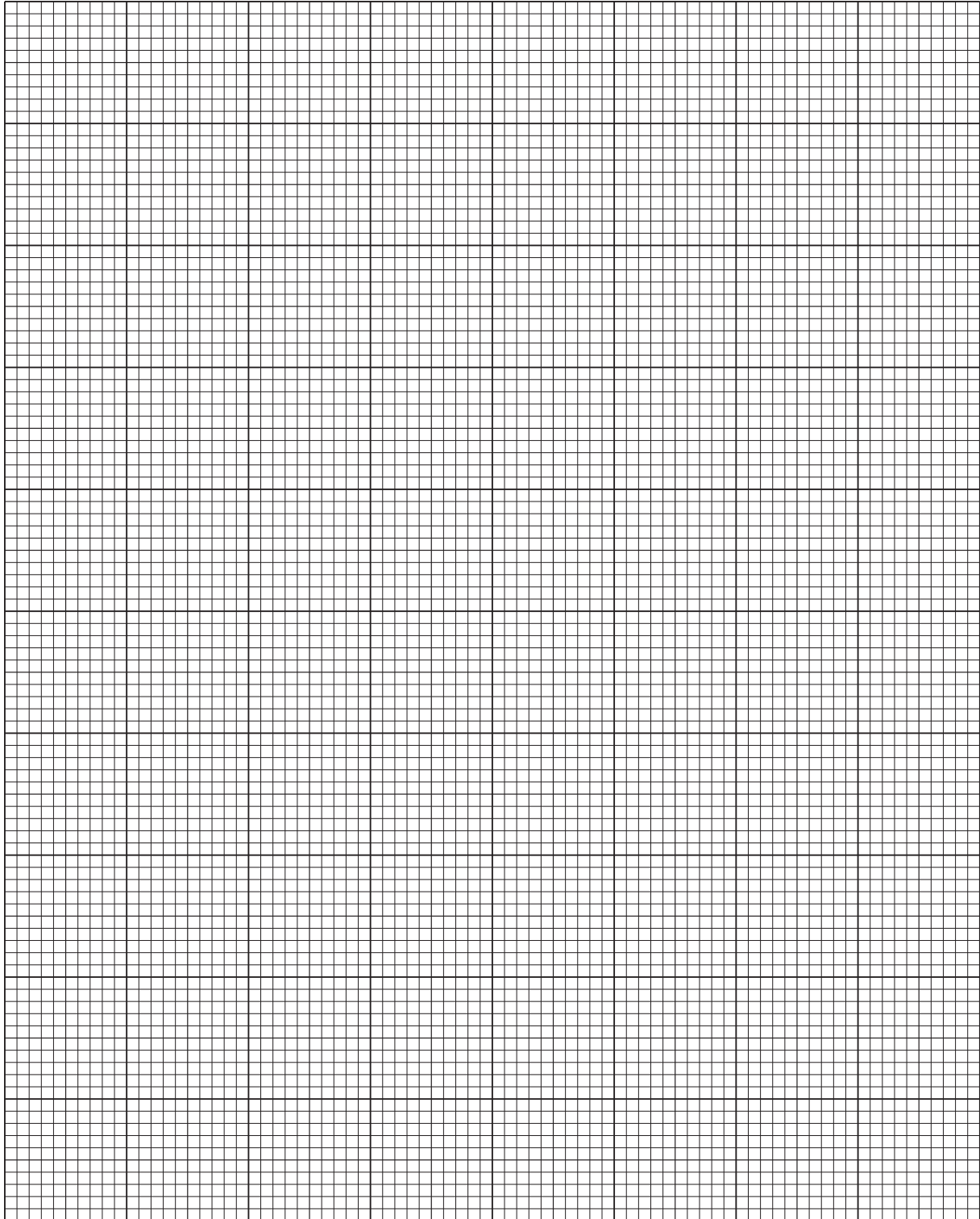
time / minutes	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7
temperature / °C							

I	
II	
III	

[3]

- (b) (i)** Plot a graph of temperature (on the y-axis) against time (on the x-axis) on the grid. The scale for the y-axis should extend 15°C above the maximum temperature you recorded.

Label any points you consider to be anomalous.



I	
II	
III	

[3]

- (ii) Draw two lines of best fit on your graph. The first is for the temperature before adding **FA 4** and the second is for the cooling of the mixture. Extrapolate both lines to 2 minutes and determine the theoretical temperature rise at this time.

theoretical temperature rise at 2 minutes = ... °C [2]

(c) Calculations

- (i) Use your answer to **(b)(ii)** to calculate the energy change when **FA 4** is added to **FA 3**.

energy change = ... J [1]

- (ii) Use your answer to **(c)(i)** to calculate the enthalpy change, ΔH , in kJ mol^{-1} , when 1 mol of magnesium reacts with hydrochloric acid, **FA 3**.

Show your working.

$\Delta H = \underset{\text{sign}}{\text{.....}} \underset{\text{value}}{\text{.....}} \text{ kJ mol}^{-1}$ [2]

- (iii) Use your answer to **(c)(ii)** and the fact that the literature value of the enthalpy change of this reaction is -452 kJ mol^{-1} (of Mg) to calculate the percentage purity of your sample of magnesium.

purity of Mg = ... % [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 (a) Devise and carry out tests to determine whether **FA 5** is magnesium carbonate. Record your tests, observations and conclusions in the space below.

[5]

- (b) (i) **FA 6** is an aqueous solution containing two anions and two cations. Three of these ions are included in the Qualitative analysis notes.

Carry out the following tests using a 1 cm depth of **FA 6** in a test-tube for each test.

Record your observations for each test in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide.	
Test 2 Add an equal depth of hydrogen peroxide, then divide the solution into two portions. ----- To the first portion, add a few drops of starch solution. ----- To the second portion, add aqueous sodium hydroxide.	
Test 3 Add a few drops of aqueous silver nitrate, then ----- add aqueous ammonia.	
Test 4 Add a few drops of aqueous barium chloride or barium nitrate, then ----- add nitric acid.	
Test 5 Add a few drops of acidified aqueous potassium manganate(VII).	

- (ii) Identify as many ions present in **FA 6** as possible from your observations in **(b)(i)**.

Write the formulae of these ions in Table 3.2. If an ion cannot be positively identified from the tests, write 'unknown' in the space.

Table 3.2

cations	anions

[3]

- (c) Acidified potassium manganate(VII) acts as an oxidising agent.

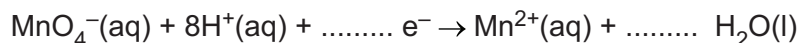
- (i) State the colour change that occurs when acidified potassium manganate(VII) oxidises aqueous sodium nitrite.

colour change from to [1]

- (ii) The change in oxidation number is equal to the number of electrons added to or subtracted from a reactant. An equation which includes electrons is called a half-equation.

The incomplete half-equation for acidified potassium manganate(VII) acting as an oxidising agent is shown.

Balance the half-equation for acidified potassium manganate(VII).



[1]

[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											1		13	14	15	16	17	18							
		Key																2								
		atomic number atomic symbol name relative atomic mass																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	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	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 oganesson —									

lanthanoids

actinoids

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