



Cambridge International AS & A Level

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NAME

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

October/November 2025

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

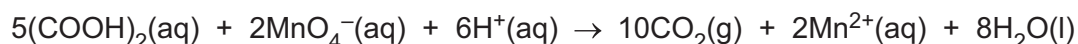
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

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

- 1 Hydrated ethanedioic acid is a diprotic acid with the formula $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ where **x** is an integer.

Ethanedioic acid reacts with manganate(VII) ions when heated.



You will determine the value of **x** in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ by titrating a solution containing ethanedioic acid with manganate(VII) ions.

- **FA 1** is 6.20 g dm^{-3} aqueous ethanedioic acid, $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.
- **FA 2** is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .
- **FA 3** is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 20 cm^3 of **FA 3** to the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70°C .
- Remove the flame.
- Carefully lift the hot conical flask and place it on the white tile under the burette.
- Add **FA 2** drop-wise for the first $2\text{--}3 \text{ cm}^3$. Any initial pink colouring may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70°C . If the brown colour disappears, continue the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- The end-point is reached when a permanent pale pink colour is formed.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FA 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 **FA 1** required cm³ of **FA 2**. [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 manganate(VII) ions, MnO_4^- , in the volume of **FA 2** calculated in **(b)**.

amount of MnO_4^- = ... mol [1]

- (iii) Calculate the amount, in mol, of ethanedioic acid that reacts with the manganate(VII) ions in **(c)(ii)**.

amount of $(\text{COOH})_2$ = ... mol

Hence calculate the concentration, in mol dm^{-3} , of ethanedioic acid in **FA 1**.

concentration of $(\text{COOH})_2$ = ... mol dm^{-3} [2]

- (iv) Calculate the relative molecular mass, M_r , of the ethanedioic acid in **FA 1**.

M_r = ... [1]

- (v) Calculate the value of **x** in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.

Show your working.

x = ... [1]

- (d) Explain why it is necessary to add **FA 3** in each titration.

.....
 [1]

[Total: 15]



2 Hydrated zinc sulfate has the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ where y is an integer.

Hydrated zinc sulfate decomposes when heated, losing only its water of crystallisation and becoming anhydrous.

You will determine the value of y in $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ by heating the hydrated salt until it becomes anhydrous.

FA 4 is hydrated zinc sulfate, $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass in the space for Results.
- Add between 3.20 g and 3.40 g of **FA 4** to the crucible.
- Weigh the crucible with its lid and **FA 4**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

You may wish to begin work on Question 3 while the crucible is cooling.

- Weigh the crucible with its lid and its contents. Record the mass.
- Remove the lid. Heat the crucible strongly for approximately 3 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Weigh the crucible with its lid and its contents. Record the mass.
- Calculate the mass of **FA 4** used and the mass of residue obtained. Record the masses.

Results

I	
II	
III	
IV	
V	

[5]



(b) Calculations

- (i) Calculate the amount, in mol, of anhydrous zinc sulfate residue formed in the decomposition of **FA 4**.

amount of ZnSO_4 = ... mol

Calculate the amount, in mol, of water of crystallisation lost.

amount of H_2O = ... mol
[2]

- (ii) Calculate the value of **y** in the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

Show your working.

y = ... [2]

- (c) A student suggests using this thermal decomposition method to investigate the number of moles of water of crystallisation in hydrated ethanedioic acid. The teacher says that this method is unsuitable.

Suggest why this method is unsuitable.

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

[Total: 10]



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) A bottle labelled **FA 5** is thought to contain hydrated zinc sulfate. It would therefore contain zinc ions and sulfate ions as well as water of crystallisation.

- (i) Devise and carry out tests to investigate whether zinc ions, sulfate ions and water of crystallisation are present.

Record the tests you carry out and the observations you see in the space provided.



- (ii) Use your observations in (a)(i) to complete Table 3.1 to show whether each species is present in **FA 5**.

Use a tick (✓) if the species is present.

Use a cross (✗) if the species is **not** present.

Table 3.1

Zn^{2+}	
SO_4^{2-}	
H_2O	

[1]

- (b) You are provided with solid **FA 6**.

- (i) Heat a few crystals of **FA 6** in a hard-glass test-tube until no further gas is evolved. Record all your observations.

Leave the test-tube until it is cool.

Keep the cooled residue for use in (b)(ii).

.....

 [2]

- (ii) To the cooled residue from (b)(i), add approximately 3 cm depth of distilled water and stir. Filter the solution formed into a test-tube.

The colour of the solution is [1]



(c) You are provided with aqueous solutions **FA 7** and **FA 8** and with solid **FA 9**.

FA 7 is an aqueous solution of **FA 6**.

FA 7, **FA 8** and **FA 9** contain compounds which all have one metal that is the same but which may be in different oxidation states.

- (i) Carry out the following tests on **FA 7**, **FA 8** and **FA 9** and record your observations in Table 3.2. For each test use a 1 cm depth of a solution or a spatula measure of solid.

Table 3.2

test	observations		
	FA 7	FA 8	FA 9
Test 1 Add hydrogen peroxide.			
Test 2 Add aqueous sodium hydroxide, then			
leave to stand.			
Test 3 Add aqueous iron(II) sulfate.			

[4]

- (ii) Suggest the identity of the metal in **FA 6/FA 7**, **FA 8** and **FA 9**.

The metal is

[1]

- (iii) Complete Table 3.3 to suggest the oxidation state of the metal in **FA 6/FA 7** and **FA 8**.

Table 3.3

	FA 6/FA 7	FA 8
oxidation state		

[1]

[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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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	
Li lithium 6.9	Be beryllium 9.0											B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2			
11	12											13	14	15	16	17	18			
Na sodium 23.0	Mg magnesium 24.3											Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9			
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36			
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8			
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54			
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3			
55	56	57–71 lanthanoids		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86		
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	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 —		

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	144.2	—	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	mendeleevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—





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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

October/November 2025

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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Session

Laboratory

For Examiner's Use

1

2

3

Total

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



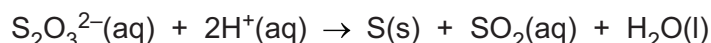
Quantitative analysis

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 for the solid sulfur forming to obscure the print on the insert.

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, add the reaction mixture to 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.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready to use in **Experiment 2**.

Experiment 2

- Refill the burette with **FA 1**.
- Fill the second burette with distilled water.
- Run 20.00 cm^3 of **FA 1** into the 100 cm^3 beaker.
- Run 20.00 cm^3 of distilled water into the same 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.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is 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: 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) (i) On the grid in Fig. 1.1, 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.



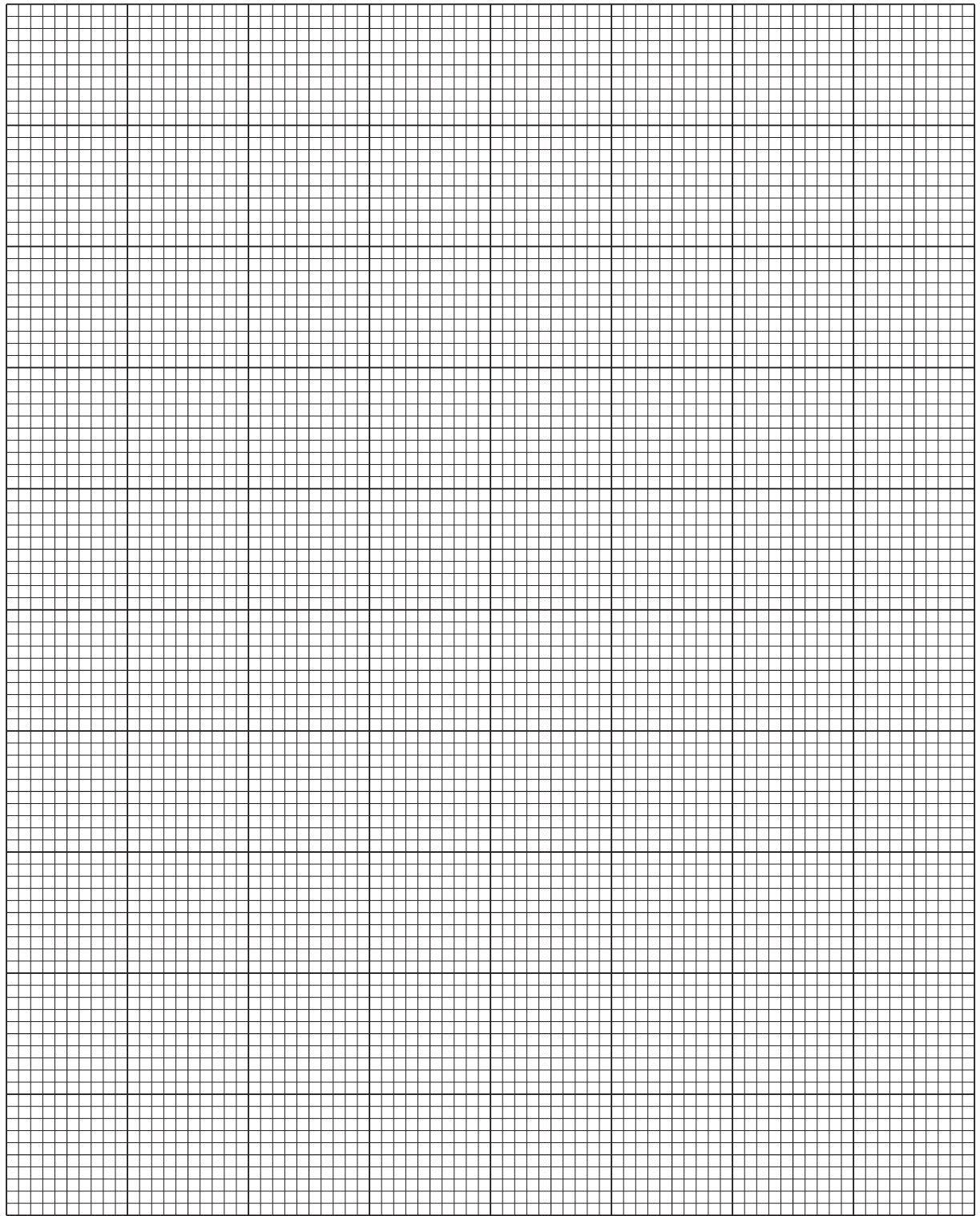


Fig. 1.1

I	
II	
III	

[3]

[Turn over]



- (ii) Use your graph in Fig. 1.1 to determine the time it would take for the print to be obscured if 7.50 cm^3 of **FA 1**, 32.50 cm^3 of water and 10.0 cm^3 of **FA 2** had been used. Show clearly on the graph how you worked out your answer.

time for printing to be obscured = ... s [2]

- (c) A student carries out the same method as given in (a) but using a different concentration of acid. The student's calculated values for the rate are plotted on the grid in Fig. 1.2.

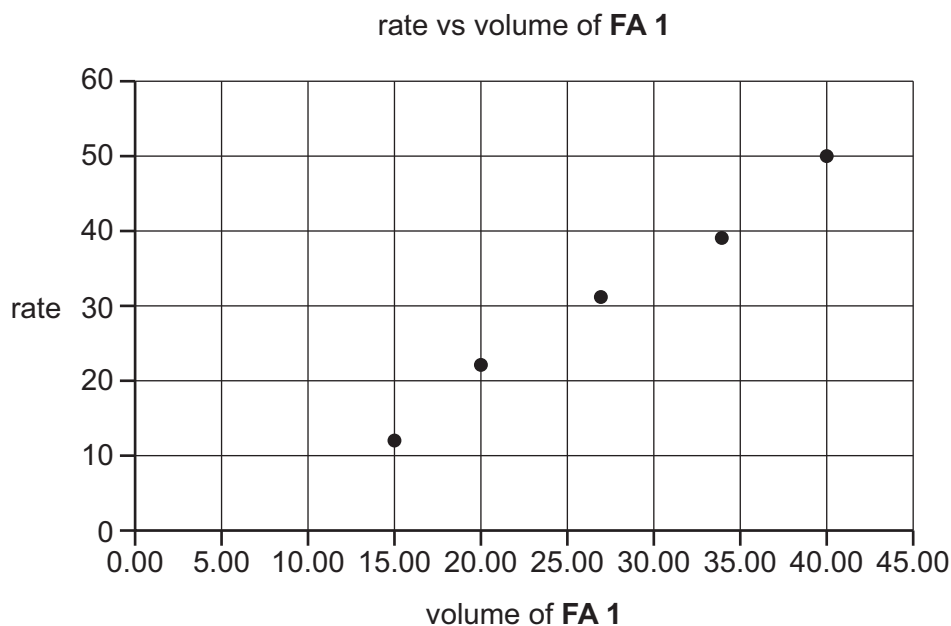


Fig. 1.2

State whether the student's results show that the rate is directly proportional to the volume of **FA 1** used.
Explain your answer.

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

[Total: 15]





- 2 When hydrated sodium thiosulfate is dissolved in water the temperature of the liquid changes. You will carry out an experiment to determine the enthalpy change, ΔH , when one mole of hydrated sodium thiosulfate dissolves in water.

FA 3 is hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of distilled water into the cup.
- Measure the temperature of the water in the cup. Record this in the space for results.
- Weigh the container with **FA 3**. Record the mass.
- Tip all the **FA 3** into the cup.
- Stir the mixture until the minimum temperature is obtained. Record this temperature.
- Weigh the container with any residual **FA 3**. Record the mass.
- Calculate and record the mass of **FA 3** added.
- Calculate and record the temperature change.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the amount, in mol, of hydrated sodium thiosulfate added.

amount of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ = ... mol [1]

- (ii) Calculate the energy change, in J, in your experiment.

energy change = ... J [1]

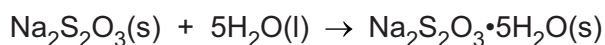


- (iii) Calculate the enthalpy change, ΔH , in kJ mol^{-1} , when 1.00 mol of hydrated sodium thiosulfate dissolves in water. Show your working.

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

sign *value* [1]

- (c) The value calculated in (b)(iii) can be used to determine the enthalpy change, ΔH_r , for the following reaction.



Outline the method of one further experiment you would need to carry out to obtain the data necessary to calculate the value of ΔH_r .

Show how you would use your results from this experiment and (b)(iii) to calculate ΔH_r .

Do **not** carry out your experiment.

method

.....

.....

calculation

.....

[4]

[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. 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 Half-fill the 250 cm³ beaker with water and place it on a tripod and gauze. Heat the water until boiling then switch off your Bunsen burner. This will be your hot water bath for use in **(b)(i)**. Start **(a)(i)** while the water is heating.

(a) **FA 4** is an aqueous solution containing three ions. One ion is **not** listed in the Qualitative analysis notes. **FA 5** is an aqueous solution containing two ions. The cation in **FA 5** is listed in the Qualitative analysis notes. The anions in both **FA 4** and **FA 5** contain sulfur.

- (i)** Carry out the following tests using a 1 cm depth of either **FA 4** or **FA 5** in a test-tube. Record your observations in Table 3.1.



Table 3.1

<i>test</i>	<i>observations</i>	
	FA 4	FA 5
Test 1 Add aqueous sodium hydroxide.		
Test 2 Add aqueous ammonia.		
Test 3 Add aqueous sodium carbonate.		
Test 4 Add aqueous barium chloride or aqueous barium nitrate.		
Test 5 Add acidified aqueous potassium manganate(VII).		

[5]

- (ii) From your observations in (a)(i), deduce the identities of the ions present in **FA 4** and **FA 5**. Give the formula of each ion in Table 3.2. If you are unable to identify an ion write 'unknown'.

Table 3.2

<i>ions present</i>	FA 4	FA 5
cations		
anions		

[3]





- (b) (i) Both **FA 6** and **FA 7** are one of propan-1-ol, propan-2-ol, methanoic acid or ethanoic acid. You will carry out tests to investigate the identities of **FA 6** and **FA 7**. For each test use a 1 cm depth of **FA 6** or **FA 7** in a test-tube. Record your observations in Table 3.3.

Table 3.3

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
Test 1 Add a few drops of acidified aqueous potassium manganate(VII), then		
place the test-tube in the hot water bath.		
Test 2 Add a 2 cm depth of aqueous iodine followed by drops of aqueous sodium hydroxide until the colour just disappears.		
If no reaction is visible, place the test-tube in the hot water bath.		
Test 3 Add aqueous sodium carbonate.		

[3]

- (ii) From your observations in (b)(i) deduce the identities of **FA 6** and **FA 7**. Give reasons for your answers.

FA 6 is

reasons

.....

FA 7 is

reasons

.....

[2]



- (c) A student carrying out a similar set of tests identifies two unknown compounds to be ethanol and propanoic acid.

Write an equation for the reaction between these two compounds.

..... [1]

[Total: 14]



Qualitative analysis notes

1 Reactions of cations

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

2 Reactions of anions

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

3 Tests for gases

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

4 Tests for elements

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

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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																			
		atomic number atomic symbol name relative atomic mass																			
3 Li lithium 6.9	4 Be beryllium 9.0																				
11 Na sodium 23.0	12 Mg magnesium 24.3																				
		3	4	5	6	7	8	9	10	11	12										
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	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 —	86 Rn radon —				
87 Fr francium —	88 Ra radium —	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 —	118 Og oganeson —				

lanthanoids

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 —

actinoids





Cambridge International AS & A Level

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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

October/November 2025

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.

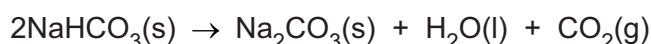
Quantitative analysis

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

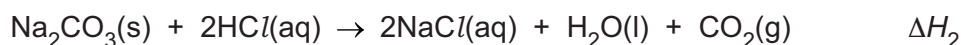
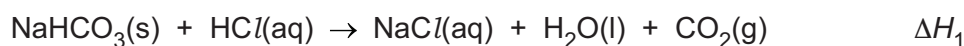
Show the precision of the apparatus you used in the data you record.

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

- 1 Sodium carbonate can be manufactured using a two-step process. The first step involves making sodium hydrogencarbonate, NaHCO_3 , which is then converted into sodium carbonate, Na_2CO_3 , in the second step of the process by the following reaction.



In this experiment you will determine the enthalpy change, ΔH_r , for this reaction. You will do this by calculating the enthalpy changes when separate samples of sodium hydrogencarbonate and sodium carbonate are added to excess hydrochloric acid, $\text{HCl}(\text{aq})$. You will then combine these values using Hess's law.



FB 1 is 2.0 mol dm^{-3} hydrochloric acid, HCl .

FB 2 is sodium hydrogencarbonate, NaHCO_3 .

FB 3 is sodium carbonate, Na_2CO_3 .

(a) Method

Experiment 1

- Support a cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FB 1** into the cup.
- Weigh the container with **FB 2**. Record the mass.
- Measure the temperature of the acid in the cup. Record this temperature.
- Carefully add all of the **FB 2**, in small portions to avoid acid spray. Stir to dissolve. Record the lowest temperature.
- Reweigh the container with any residual **FB 2**. Record the mass.
- Calculate and record the mass of **FB 2** used.
- Calculate and record the decrease in temperature.

Experiment 2

- Support the second cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FB 1** into the second cup.
- Weigh the container with **FB 3**. Record the mass.
- Measure the temperature of the acid in the cup. Record this temperature.
- Carefully add all of the **FB 3**, in small portions to avoid acid spray. Stir to dissolve. Record the highest temperature.
- Reweigh the container with any residual **FB 3**. Record the mass.
- Calculate and record the mass of **FB 3** used.
- Calculate and record the increase in temperature.

Keep FB 1 for use in Question 3.



Results

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the amount, in mol, of **FB 2** that reacts with **FB 1** and the amount, in mol, of **FB 3** that reacts with **FB 1**.

Experiment 1	Experiment 2
amount of FB 2 = ... mol	amount of FB 3 = ... mol

[2]

- (ii) Calculate the energy changes, in J, for each reaction.

Experiment 1	Experiment 2
energy change = ... J	energy change = ... J

[1]

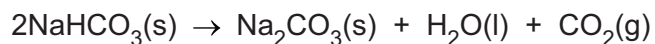
- (iii) Calculate the enthalpy change, ΔH , in kJ mol^{-1} for each reaction.

Experiment 1	Experiment 2
$\Delta H_1 =$ kJ mol^{-1} <i>sign</i> <i>value</i>	$\Delta H_2 =$ kJ mol^{-1} <i>sign</i> <i>value</i>

[2]



- (iv) Construct an enthalpy cycle and use Hess's law to determine the enthalpy change, ΔH_r , for the reaction shown.
Show your working.



(If you were unable to calculate values in (b)(iii) then assume that ΔH_1 is $+27.3 \text{ kJ mol}^{-1}$ and that ΔH_2 is $-24.9 \text{ kJ mol}^{-1}$. These may **not** be the correct values.)

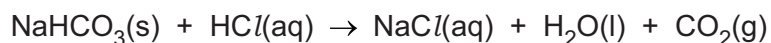
$$\Delta H_r = \begin{array}{cc} \text{.....} & \text{.....} \\ \text{sign} & \text{value} \end{array} \text{ kJ mol}^{-1}$$

[2]

[Total: 11]



- 2 In this experiment you will determine the percentage by mass of a sodium halide impurity present in a sample of sodium hydrogencarbonate by titration.



FB 4 is an aqueous solution made by dissolving 17.20 g of the impure sodium hydrogencarbonate in each dm^3 of solution.

FB 5 is $0.200 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FB 6 is methyl orange indicator.

(a) Method

- Fill the burette with **FB 5**.
- Pipette 25.0 cm^3 of **FB 4** into a conical flask.
- Add several drops of **FB 6** 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 all your burette readings and the volume of **FB 5** added in each accurate titration.

Keep FB 4 for use in Question 3.

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 cm^3 of **FB 4** required cm^3 of **FB 5**. [1]



(c) Calculations

- (i) Give your answers to **(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 hydrochloric acid in your mean titre.

amount of HCl = ... mol

Hence determine the amount, in mol, of sodium hydrogencarbonate present in 25.0 cm^3 of **FB 4**.

amount of NaHCO_3 = ... mol [1]

- (iii) Calculate the mass of sodium hydrogencarbonate present in each dm^3 of solution.

mass of NaHCO_3 = ... g

Hence calculate the percentage by mass of the sodium halide impurity in **FB 4**.
Show your working.

percentage by mass = ... % [2]

- (d) A student carries out the experiment in Question 1 using the impure sodium hydrogencarbonate dissolved to make **FB 4**.

State how this affects the value of ΔH_1 determined in **1(b)(iii)** compared to the value the student would get if pure sodium hydrogencarbonate were used.

.....
.....

State what assumption you have made about the sodium halide impurity.

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

[Total: 14]



Qualitative analysis

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

Examples of observations include:

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

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

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

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

If any solution is warmed, a boiling tube must be used. If any 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) To a 1 cm depth of **FB 4** in a boiling tube, slowly add a 1 cm depth of dilute nitric acid. Stir gently until the reaction is complete. Use this solution for your tests.
Select reagents to identify which sodium halide is present.
Record details of the reagents used and your observations.
Identify the sodium halide that is present as an impurity in **FB 4**.

The formula of the impurity is

[2]

- (ii) Suggest why it is necessary to add the nitric acid to **FB 4** before carrying out your tests in (a)(i).

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



(b) **FB 7** contains a metal cation which is listed in the Qualitative analysis notes.

- (i) Place half the sample of **FB 7** in a hard-glass test-tube. Heat gently at first and then more strongly.
Record your observations.

.....

 [2]

- (ii) Use the 25 cm³ measuring cylinder to measure 20 cm³ of **FB 1**.
Place the remaining sample of **FB 7** in a boiling tube and add portions of **FB 1** from the measuring cylinder until all the **FB 7** has reacted. Stir until the reaction is complete.
Record your observations.

Keep this solution for use in (b)(iii).

.....

 [2]

- (iii) Carry out the following tests. For each test use a 1 cm depth of the solution from (b)(ii) in a test-tube.
Record your observations in Table 3.1.
Identify the metal ion present in **FB 7**.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide.	
Test 2 Add aqueous ammonia.	
Test 3 Add a piece of aluminium foil.	

The formula of the metal ion in **FB 7** is

[4]



(c) **FB 8** is an acidified aqueous solution containing a metal cation which is listed in the Qualitative analysis notes.

- (i) Carry out the following tests. For each test use a 1 cm depth of **FB 8** in a test-tube. Record your observations in Table 3.2. Identify the metal ion present in **FB 8**.

Table 3.2

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide.	
Test 2 Add a 1 cm depth of acidified aqueous potassium manganate(VII).	

The formula of the metal ion in **FB 8** is

[3]

- (ii) State the type of reaction between the metal ion in **FB 8** and acidified aqueous potassium manganate(VII). Explain how your observations support your answer.

.....

 [1]

[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))
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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

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

anthanoids

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	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	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	—

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Cambridge International AS & A Level

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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

October/November 2025

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

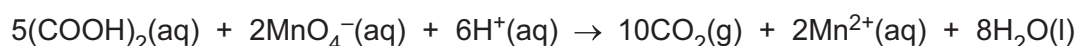
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

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

- 1 Hydrated ethanedioic acid is a diprotic acid with the formula $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ where **x** is an integer.

Ethanedioic acid reacts with manganate(VII) ions when heated.



You will determine the value of **x** in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ by titrating a solution containing ethanedioic acid with manganate(VII) ions.

- **FA 1** is 6.20 g dm^{-3} aqueous ethanedioic acid, $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.
- **FA 2** is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .
- **FA 3** is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 20 cm^3 of **FA 3** to the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70°C .
- Remove the flame.
- Carefully lift the hot conical flask and place it on the white tile under the burette.
- Add **FA 2** drop-wise for the first $2\text{--}3 \text{ cm}^3$. Any initial pink colouring may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70°C . If the brown colour disappears, continue the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- The end-point is reached when a permanent pale pink colour is formed.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FA 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 **FA 1** required cm³ of **FA 2**. [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 manganate(VII) ions, MnO_4^- , in the volume of **FA 2** calculated in **(b)**.

amount of MnO_4^- = ... mol [1]

- (iii) Calculate the amount, in mol, of ethanedioic acid that reacts with the manganate(VII) ions in **(c)(ii)**.

amount of $(\text{COOH})_2$ = ... mol

Hence calculate the concentration, in mol dm^{-3} , of ethanedioic acid in **FA 1**.

concentration of $(\text{COOH})_2$ = ... mol dm^{-3} [2]

- (iv) Calculate the relative molecular mass, M_r , of the ethanedioic acid in **FA 1**.

M_r = ... [1]

- (v) Calculate the value of **x** in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.

Show your working.

x = ... [1]

- (d) Explain why it is necessary to add **FA 3** in each titration.

.....
 [1]

[Total: 15]



2 Hydrated zinc sulfate has the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ where y is an integer.

Hydrated zinc sulfate decomposes when heated, losing only its water of crystallisation and becoming anhydrous.

You will determine the value of y in $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ by heating the hydrated salt until it becomes anhydrous.

FA 4 is hydrated zinc sulfate, $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass in the space for Results.
- Add between 3.20 g and 3.40 g of **FA 4** to the crucible.
- Weigh the crucible with its lid and **FA 4**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

You may wish to begin work on Question 3 while the crucible is cooling.

- Weigh the crucible with its lid and its contents. Record the mass.
- Remove the lid. Heat the crucible strongly for approximately 3 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Weigh the crucible with its lid and its contents. Record the mass.
- Calculate the mass of **FA 4** used and the mass of residue obtained. Record the masses.

Results

I	
II	
III	
IV	
V	

[5]



(b) Calculations

- (i) Calculate the amount, in mol, of anhydrous zinc sulfate residue formed in the decomposition of **FA 4**.

amount of ZnSO_4 = ... mol

Calculate the amount, in mol, of water of crystallisation lost.

amount of H_2O = ... mol
[2]

- (ii) Calculate the value of **y** in the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

Show your working.

y = ... [2]

- (c) A student suggests using this thermal decomposition method to investigate the number of moles of water of crystallisation in hydrated ethanedioic acid. The teacher says that this method is unsuitable.

Suggest why this method is unsuitable.

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

[Total: 10]



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) A bottle labelled **FA 5** is thought to contain hydrated zinc sulfate. It would therefore contain zinc ions and sulfate ions as well as water of crystallisation.

- (i) Devise and carry out tests to investigate whether zinc ions, sulfate ions and water of crystallisation are present.

Record the tests you carry out and the observations you see in the space provided.



- (ii) Use your observations in (a)(i) to complete Table 3.1 to show whether each species is present in **FA 5**.

Use a tick (✓) if the species is present.

Use a cross (✗) if the species is **not** present.

Table 3.1

Zn^{2+}	
SO_4^{2-}	
H_2O	

[1]

- (b) You are provided with solid **FA 6**.

- (i) Heat a few crystals of **FA 6** in a hard-glass test-tube until no further gas is evolved. Record all your observations.

Leave the test-tube until it is cool.

Keep the cooled residue for use in (b)(ii).

.....

 [2]

- (ii) To the cooled residue from (b)(i), add approximately 3 cm depth of distilled water and stir. Filter the solution formed into a test-tube.

The colour of the solution is [1]



(c) You are provided with aqueous solutions **FA 7** and **FA 8** and with solid **FA 9**.

FA 7 is an aqueous solution of **FA 6**.

FA 7, **FA 8** and **FA 9** contain compounds which all have one metal that is the same but which may be in different oxidation states.

- (i) Carry out the following tests on **FA 7**, **FA 8** and **FA 9** and record your observations in Table 3.2. For each test use a 1 cm depth of a solution or a spatula measure of solid.

Table 3.2

test	observations		
	FA 7	FA 8	FA 9
Test 1 Add hydrogen peroxide.			
Test 2 Add aqueous sodium hydroxide, then	X		
leave to stand.			
Test 3 Add aqueous iron(II) sulfate.			X

[4]

- (ii) Suggest the identity of the metal in **FA 6/FA 7**, **FA 8** and **FA 9**.

The metal is

[1]

- (iii) Complete Table 3.3 to suggest the oxidation state of the metal in **FA 6/FA 7** and **FA 8**.

Table 3.3

	FA 6/FA 7	FA 8
oxidation state		

[1]

[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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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															
		</															



Cambridge International AS & A Level

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CHEMISTRY

9701/36

Paper 3 Advanced Practical Skills 2

October/November 2025

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

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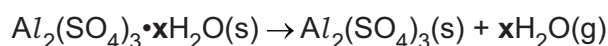
Quantitative analysis

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 Many hydrated salts decompose when heated, losing water of crystallisation. The number of molecules of water of crystallisation, **x**, in hydrated aluminium sulfate can be determined by heating until it becomes anhydrous: **x** is an integer.



FB 1 is hydrated aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Add between 1.80 and 2.00 g of **FB 1** to the crucible.
- Weigh the crucible, lid and **FB 1**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 5 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

While the crucible is cooling, you should begin work on Questions 2 or 3.

- Reweigh the crucible and contents with the lid on. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further 2 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Reweigh the crucible and residue with the lid on. Record the mass.
- Calculate and record the mass of **FB 1** used, the mass of residue obtained and the mass lost during heating.

Results

I	
II	
III	
IV	
V	

[5]



(b) Calculations

- (i) Calculate the amount, in mol, of water of crystallisation lost during the thermal decomposition of **FB 1**.

amount of H_2O lost = ... mol [1]

- (ii) Calculate the amount, in mol, of anhydrous residue produced by the thermal decomposition. Show your working.

amount of $\text{Al}_2(\text{SO}_4)_3$ produced = ... mol [1]

- (iii) Calculate the number of molecules of water of crystallisation in the formula of hydrated aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$.

$x =$ [1]

- (c) (i) State how the appearance of the residue compares with the appearance of the hydrated solid before heating.

.....
 [1]

- (ii) Suggest why the crucible and contents are heated with the crucible lid **on** for the first two minutes of the experiment.

.....

 [1]

- (iii) A student carries out the experiment in (a), but obtains a value for x that is higher than expected. The student suggests that this could be because the hydrated aluminium sulfate is contaminated with some anhydrous aluminium sulfate.

State whether the student's suggestion is correct.
 Explain your answer.

.....

 [1]



- 2 The number of molecules of water of crystallisation, **y**, in hydrated iron(II) sulfate can be determined by titration with acidified potassium manganate(VII): **y** is an integer.

FB 2 is aqueous iron(II) sulfate, containing 30.00 g dm^{-3} of $\text{FeSO}_4 \cdot y\text{H}_2\text{O}$.

FB 3 is aqueous potassium manganate(VII), containing 3.48 g dm^{-3} of KMnO_4 .

FB 4 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) **Method**

- Fill the burette with **FB 3**.
- Pipette 25.0 cm^3 of **FB 2** into a conical flask.
- Use the 25 cm^3 measuring cylinder to transfer approximately 10 cm^3 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 your burette readings and the volume of **FB 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to be used in your calculations.

Show clearly how you obtained this value.

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



(c) Calculations

- (i) Calculate the amount, in mol, of potassium manganate(VII) present in the volume of **FB 3** in **(b)**. Show your working.

amount of $\text{KMnO}_4 = \dots\dots\dots \text{mol}$ [2]

- (ii) An incomplete equation for the reaction of iron(II) ions with manganate(VII) ions is shown. The mole ratio of Fe^{2+} and MnO_4^- is given correctly. Complete the equation.



- (iii) Calculate the concentration of iron(II) sulfate, in mol dm^{-3} , in **FB 2**.

concentration of $\text{FeSO}_4 = \dots\dots\dots \text{mol dm}^{-3}$ [1]

- (iv) Calculate the value of **y** in $\text{FeSO}_4 \cdot y\text{H}_2\text{O}$.

y = $\dots\dots\dots$ [2]

- (d) A student suggests that the experiment is more accurate if **FB 4** is measured with a pipette.

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

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

- (e) Aqueous solutions of iron(II) sulfate are slowly oxidised by air.
State what effect this oxidation would have on the value of **y** calculated in **(c)(iv)**.
Explain your answer.

.....
.....
..... [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. 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) Use very small quantities of solid **FB 5** and carry out each of the tests described in Table 3.1. Identify any gases produced.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Pour a 1 cm depth of aqueous iron(III) chloride into a test-tube. Add a small spatula measure of FB 5 . Leave the test-tube to stand for about 3 minutes, then	
pour off some of the solution into another test-tube and add aqueous sodium hydroxide.	
Test 2 Pour a 1 cm depth of aqueous copper(II) sulfate into a test-tube. Add a small quantity of FB 5 . Leave the test-tube to stand for about 3 minutes.	
Test 3 Pour a 1 cm depth of dilute sulfuric acid into a test-tube and add 2 drops of aqueous copper(II) sulfate. Then add a small quantity of FB 5 .	

[4]





- (ii) **FB 6** is the filtrate obtained after filtering the mixture that remains at the end of **Test 3** in (a)(i).
Add aqueous ammonia to **FB 6**.
Record your observations.

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

- (iii) Identify **FB 5**.

FB 5 is [1]

- (iv) Using your observations, explain why the reaction in **Test 2** is a redox reaction.

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

- (v) Give the ionic equation for the first reaction observed in (a)(ii). Include state symbols.

..... [1]

- (b) **FB 7** contains one anion and one cation. The anion contains oxygen but not nitrogen.
Both ions are listed in the Qualitative analysis notes.

- (i) Transfer a small spatula measure of **FB 7** into a hard-glass test-tube.
Heat gently at the start, then strongly until no further change occurs.
Leave the test-tube to cool.

Record all your observations. Identify any gases produced.

.....
.....
.....
.....
..... [3]

- (ii) Carry out **one** further positive test to confirm the identity of the **anion** in **FB 7**.

Record **only** the results shown in a positive test.
Describe the test you carry out and the observations you make in the space below.

The anion in **FB 7** 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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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																	
3	4	5	6	7	8	9	10	11	12										
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	144.2
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	meitnerium	258.0
102	No	nobelium	259.0
103	Lr	lawrencium	262.0

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CHEMISTRY

9701/37

Paper 3 Advanced Practical Skills 1

October/November 2025

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

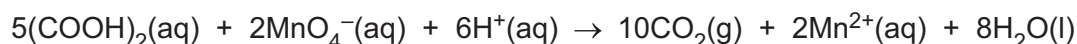
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

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

- 1 Hydrated ethanedioic acid is a diprotic acid with the formula $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ where **x** is an integer.

Ethanedioic acid reacts with manganate(VII) ions when heated.



You will determine the value of **x** in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ by titrating a solution containing ethanedioic acid with manganate(VII) ions.

- **FA 1** is 6.20 g dm^{-3} aqueous ethanedioic acid, $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.
- **FA 2** is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .
- **FA 3** is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 20 cm^3 of **FA 3** to the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70°C .
- Remove the flame.
- Carefully lift the hot conical flask and place it on the white tile under the burette.
- Add **FA 2** drop-wise for the first $2\text{--}3 \text{ cm}^3$. Any initial pink colouring may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70°C . If the brown colour disappears, continue the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- The end-point is reached when a permanent pale pink colour is formed.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FA 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 **FA 1** required cm³ of **FA 2**. [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 manganate(VII) ions, MnO_4^- , in the volume of **FA 2** calculated in **(b)**.

amount of MnO_4^- = ... mol [1]

- (iii) Calculate the amount, in mol, of ethanedioic acid that reacts with the manganate(VII) ions in **(c)(ii)**.

amount of $(\text{COOH})_2$ = ... mol

Hence calculate the concentration, in mol dm^{-3} , of ethanedioic acid in **FA 1**.

concentration of $(\text{COOH})_2$ = ... mol dm^{-3} [2]

- (iv) Calculate the relative molecular mass, M_r , of the ethanedioic acid in **FA 1**.

M_r = ... [1]

- (v) Calculate the value of **x** in $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$.

Show your working.

x = ... [1]

- (d) Explain why it is necessary to add **FA 3** in each titration.

.....
 [1]

[Total: 15]



2 Hydrated zinc sulfate has the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ where y is an integer.

Hydrated zinc sulfate decomposes when heated, losing only its water of crystallisation and becoming anhydrous.

You will determine the value of y in $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$ by heating the hydrated salt until it becomes anhydrous.

FA 4 is hydrated zinc sulfate, $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass in the space for Results.
- Add between 3.20 g and 3.40 g of **FA 4** to the crucible.
- Weigh the crucible with its lid and **FA 4**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

You may wish to begin work on Question 3 while the crucible is cooling.

- Weigh the crucible with its lid and its contents. Record the mass.
- Remove the lid. Heat the crucible strongly for approximately 3 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Weigh the crucible with its lid and its contents. Record the mass.
- Calculate the mass of **FA 4** used and the mass of residue obtained. Record the masses.

Results

I	
II	
III	
IV	
V	

[5]



(b) Calculations

- (i) Calculate the amount, in mol, of anhydrous zinc sulfate residue formed in the decomposition of **FA 4**.

amount of ZnSO_4 = ... mol

Calculate the amount, in mol, of water of crystallisation lost.

amount of H_2O = ... mol
[2]

- (ii) Calculate the value of **y** in the formula $\text{ZnSO}_4 \cdot y\text{H}_2\text{O}$.

Show your working.

y = ... [2]

- (c) A student suggests using this thermal decomposition method to investigate the number of moles of water of crystallisation in hydrated ethanedioic acid. The teacher says that this method is unsuitable.

Suggest why this method is unsuitable.

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

[Total: 10]



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) A bottle labelled **FA 5** is thought to contain hydrated zinc sulfate. It would therefore contain zinc ions and sulfate ions as well as water of crystallisation.

- (i) Devise and carry out tests to investigate whether zinc ions, sulfate ions and water of crystallisation are present.

Record the tests you carry out and the observations you see in the space provided.



- (ii) Use your observations in (a)(i) to complete Table 3.1 to show whether each species is present in **FA 5**.

Use a tick (✓) if the species is present.

Use a cross (✗) if the species is **not** present.

Table 3.1

Zn^{2+}	
SO_4^{2-}	
H_2O	

[1]

- (b) You are provided with solid **FA 6**.

- (i) Heat a few crystals of **FA 6** in a hard-glass test-tube until no further gas is evolved. Record all your observations.

Leave the test-tube until it is cool.

Keep the cooled residue for use in (b)(ii).

.....

 [2]

- (ii) To the cooled residue from (b)(i), add approximately 3 cm depth of distilled water and stir. Filter the solution formed into a test-tube.

The colour of the solution is [1]



(c) You are provided with aqueous solutions **FA 7** and **FA 8** and with solid **FA 9**.

FA 7 is an aqueous solution of **FA 6**.

FA 7, **FA 8** and **FA 9** contain compounds which all have one metal that is the same but which may be in different oxidation states.

(i) Carry out the following tests on **FA 7**, **FA 8** and **FA 9** and record your observations in Table 3.2. For each test use a 1 cm depth of a solution or a spatula measure of solid.

Table 3.2

test	observations		
	FA 7	FA 8	FA 9
Test 1 Add hydrogen peroxide.			
Test 2 Add aqueous sodium hydroxide, then			
leave to stand.			
Test 3 Add aqueous iron(II) sulfate.			

[4]

(ii) Suggest the identity of the metal in **FA 6/FA 7**, **FA 8** and **FA 9**.

The metal is

[1]

(iii) Complete Table 3.3 to suggest the oxidation state of the metal in **FA 6/FA 7** and **FA 8**.

Table 3.3

	FA 6/FA 7	FA 8
oxidation state		

[1]

[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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 Li lithium 6.9	4 Be beryllium 9.0																				
11 Na sodium 23.0	12 Mg magnesium 24.3	3 Sc scandium 45.0	4 Ti titanium 47.9	5 V vanadium 50.9	6 Cr chromium 52.0	7 Mn manganese 54.9	8 Fe iron 55.8	9 Co cobalt 58.9	10 Ni nickel 58.7	11 Cu copper 63.5	12 Zn zinc 65.4	13 Al 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 oganesson —				

lanthanoids

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

actinoids

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CHEMISTRY

9701/38

Paper 3 Advanced Practical Skills 2

October/November 2025

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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

INFORMATION

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

Session

Laboratory

For Examiner's Use

1

2

3

Total

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

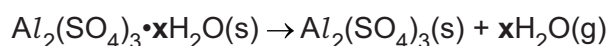
Quantitative analysis

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

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

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

- 1 Many hydrated salts decompose when heated, losing water of crystallisation. The number of molecules of water of crystallisation, **x**, in hydrated aluminium sulfate can be determined by heating until it becomes anhydrous: **x** is an integer.



FB 1 is hydrated aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Add between 1.80 and 2.00 g of **FB 1** to the crucible.
- Weigh the crucible, lid and **FB 1**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 5 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

While the crucible is cooling, you should begin work on Questions 2 or 3.

- Reweigh the crucible and contents with the lid on. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further 2 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Reweigh the crucible and residue with the lid on. Record the mass.
- Calculate and record the mass of **FB 1** used, the mass of residue obtained and the mass lost during heating.

Results

I	
II	
III	
IV	
V	

[5]



(b) Calculations

- (i) Calculate the amount, in mol, of water of crystallisation lost during the thermal decomposition of **FB 1**.

amount of H_2O lost = ... mol [1]

- (ii) Calculate the amount, in mol, of anhydrous residue produced by the thermal decomposition. Show your working.

amount of $\text{Al}_2(\text{SO}_4)_3$ produced = ... mol [1]

- (iii) Calculate the number of molecules of water of crystallisation in the formula of hydrated aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$.

$x =$ [1]

- (c) (i) State how the appearance of the residue compares with the appearance of the hydrated solid before heating.

.....
 [1]

- (ii) Suggest why the crucible and contents are heated with the crucible lid **on** for the first two minutes of the experiment.

.....

 [1]

- (iii) A student carries out the experiment in (a), but obtains a value for x that is higher than expected. The student suggests that this could be because the hydrated aluminium sulfate is contaminated with some anhydrous aluminium sulfate.

State whether the student's suggestion is correct.
 Explain your answer.

.....

 [1]



- 2 The number of molecules of water of crystallisation, **y**, in hydrated iron(II) sulfate can be determined by titration with acidified potassium manganate(VII): **y** is an integer.

FB 2 is aqueous iron(II) sulfate, containing 30.00 g dm^{-3} of $\text{FeSO}_4 \cdot y\text{H}_2\text{O}$.

FB 3 is aqueous potassium manganate(VII), containing 3.48 g dm^{-3} of KMnO_4 .

FB 4 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FB 3**.
- Pipette 25.0 cm^3 of **FB 2** into a conical flask.
- Use the 25 cm^3 measuring cylinder to transfer approximately 10 cm^3 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 your burette readings and the volume of **FB 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to be used in your calculations.

Show clearly how you obtained this value.

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



(c) Calculations

- (i) Calculate the amount, in mol, of potassium manganate(VII) present in the volume of **FB 3** in (b). Show your working.

amount of $\text{KMnO}_4 = \dots\dots\dots \text{mol}$ [2]

- (ii) An incomplete equation for the reaction of iron(II) ions with manganate(VII) ions is shown. The mole ratio of Fe^{2+} and MnO_4^- is given correctly. Complete the equation.



- (iii) Calculate the concentration of iron(II) sulfate, in mol dm^{-3} , in **FB 2**.

concentration of $\text{FeSO}_4 = \dots\dots\dots \text{mol dm}^{-3}$ [1]

- (iv) Calculate the value of **y** in $\text{FeSO}_4 \cdot y\text{H}_2\text{O}$.

y = $\dots\dots\dots$ [2]

- (d) A student suggests that the experiment is more accurate if **FB 4** is measured with a pipette.

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

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

- (e) Aqueous solutions of iron(II) sulfate are slowly oxidised by air.
State what effect this oxidation would have on the value of **y** calculated in (c)(iv).
Explain your answer.

.....
.....
..... [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. 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) Use very small quantities of solid **FB 5** and carry out each of the tests described in Table 3.1. Identify any gases produced.

Table 3.1

<i>test</i>	<i>observations</i>
Test 1 Pour a 1 cm depth of aqueous iron(III) chloride into a test-tube. Add a small spatula measure of FB 5 . Leave the test-tube to stand for about 3 minutes, then	
pour off some of the solution into another test-tube and add aqueous sodium hydroxide.	
Test 2 Pour a 1 cm depth of aqueous copper(II) sulfate into a test-tube. Add a small quantity of FB 5 . Leave the test-tube to stand for about 3 minutes.	
Test 3 Pour a 1 cm depth of dilute sulfuric acid into a test-tube and add 2 drops of aqueous copper(II) sulfate. Then add a small quantity of FB 5 .	

[4]





- (ii) **FB 6** is the filtrate obtained after filtering the mixture that remains at the end of **Test 3** in (a)(i).
Add aqueous ammonia to **FB 6**.
Record your observations.

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

- (iii) Identify **FB 5**.

FB 5 is [1]

- (iv) Using your observations, explain why the reaction in **Test 2** is a redox reaction.

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

- (v) Give the ionic equation for the first reaction observed in (a)(ii). Include state symbols.

..... [1]

- (b) **FB 7** contains one anion and one cation. The anion contains oxygen but not nitrogen.
Both ions are listed in the Qualitative analysis notes.

- (i) Transfer a small spatula measure of **FB 7** into a hard-glass test-tube.
Heat gently at the start, then strongly until no further change occurs.
Leave the test-tube to cool.

Record all your observations. Identify any gases produced.

.....
.....
.....
.....
..... [3]

- (ii) Carry out **one** further positive test to confirm the identity of the **anion** in **FB 7**.

Record **only** the results shown in a positive test.
Describe the test you carry out and the observations you make in the space below.

The anion in **FB 7** 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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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