



Cambridge International AS & A Level

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

October/November 2022

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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

INFORMATION

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

Session

Laboratory

For Examiner's Use

1

2

3

Total

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



Quantitative analysis

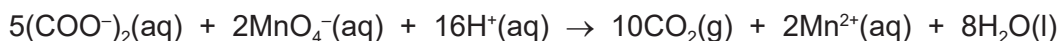
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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 Group 1 elements form salts with ethanedioic acid. These salts are ethanedioates and have the formula $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$, where **M** is the Group 1 metal.

Ethanedioate ions react with manganate(VII) ions as shown.



You will determine which metal is present in $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$ by titrating a solution of this salt with manganate(VII) ions.

FA 1 is 10.14 g dm^{-3} aqueous hydrated ethanedioate of metal **M**, $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$.

FA 2 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 3 is 1 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** into 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.
- During titrations, add **FA 2**, **slowly at first**, until a permanent pale pink colour is formed. The pink colour on initial addition may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70°C . If the brown colour disappears, continue with the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- 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 accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to 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 ethanedioate ions that reacted with the manganate(VII) ions in **(c)(ii)**.

amount of $(\text{COO}^-)_2$ = ... mol

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

concentration of $(\text{COO}^-)_2$ = ... mol dm^{-3} [1]

- (iv) Calculate the relative formula mass, M_r , of the hydrated ethanedioate, $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$.

M_r = ... [1]

- (v) Identify **M**. Show your working.

M is [2]

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

.....
 [1]

[Total: 15]

Question 2 starts on the next page.

- 2 Hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, can lose its water of crystallisation to form anhydrous copper(II) sulfate.

The enthalpy change for the dehydration of hydrated copper(II) sulfate is shown in the equation.



You will carry out experiments to determine the enthalpy changes for the solution of hydrated and anhydrous copper(II) sulfate and then use Hess's law to determine the enthalpy change of dehydration.

FA 4 is hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

FA 5 is anhydrous copper(II) sulfate, CuSO_4 .

(a) Determination of the enthalpy change of solution of hydrated copper(II) sulfate.

Method

- Weigh the container with **FA 4**. Record the mass.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 4** into the water and stir until the solid dissolves.
- Measure and record the lowest temperature reached.
- Rinse and dry the cup ready for the next experiment.
- Weigh the container with any residual **FA 4**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 4** used.

Results

[2]

(b) Calculations

- (i) Calculate the energy change during this reaction.

energy change = ... J [1]

- (ii) Calculate the amount, in mol, of hydrated copper(II) sulfate, **FA 4**, used in the experiment. Show your working.

amount of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ = ... mol [1]

- (iii) Calculate the enthalpy change, in kJ mol^{-1} , when 1.00 mol of hydrated copper(II) sulfate dissolves in water. This is the enthalpy of solution.

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

Qualitative analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

3 (a) FA 6 is an aqueous solution that contains one cation and two anions. The three ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests on **FA 6** and record your observations.

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FA 6 in a boiling tube add aqueous sodium hydroxide, then ----- heat gently.	
Test 2 To a 1 cm depth of FA 6 in a boiling tube add a 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Heat gently.	
Test 3 To a 1 cm depth of FA 6 in a test-tube add a few drops of hydrogen peroxide.	

[4]

- (ii) From your observations suggest **two** possible identities for the cation in **FA 6**.

possible cations: and [1]

- (iii) Suggest a test that would allow you to determine which of the cations you suggested in (a)(ii) is present in **FA 6**.

Carry out this test, record the result and hence identify the cation in **FA 6**.

test

result

The cation present is [2]

- (iv) From your observations in (a)(i) suggest **two** anions that could be present in **FA 6** and give their formulae.

possible anions: or [1]

- (v) Suggest an additional test that could be carried out to confirm the presence of **one** of the anions you suggested in (a)(iv).

Carry out this test, record the result and hence state the identity of the anion.

test

result

The anion present is [2]

- (b) Half fill the 250 cm³ beaker with water and heat to approximately 80 °C. Turn off the Bunsen burner. This will be your hot water bath.

FA 7 is an organic compound with an M_r between 40–57.

- (i) Carry out **Test 2** and **Test 3** on **FA 7** and record your observations. The result for **Test 1** is shown in the table.

<i>test</i>	<i>observations</i>
Test 1 Add a small piece of sodium.	no change
Test 2 To a 0.5 cm depth of aqueous iodine in a test-tube add aqueous sodium hydroxide dropwise until the yellow colour just disappears. Then add a few drops of FA 7 and shake the test-tube. If no change is seen, warm the test-tube in your hot water bath.	
Test 3 To a 1 cm depth of FA 7 in a test-tube add a few drops of acidified potassium manganate(VII). Warm the test-tube in your hot water bath.	

[2]

- (ii) Using the observations in (b)(i) suggest what can be deduced from each test about the functional groups present in **FA 7**.

Test 1

Test 2

Test 3

[2]

- (iii) Use your deductions in (b)(ii) to suggest the identity of **FA 7**.

FA 7 is [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	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																		
1	2											13	14	15	16	17	18	
3 Li lithium 6.9	4 Be beryllium 9.0	Key																2 He helium 4.0
		atomic number atomic symbol name relative atomic mass																
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 —	

lanthanoids

actinoids

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



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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

October/November 2022

2 hours

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Session	
Laboratory	

For Examiner's Use	
1	
2	
3	
Total	

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Quantitative analysis

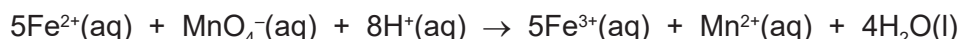
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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** An iron compound can contain Fe^{2+} ions, Fe^{3+} ions or both ions.

In this experiment, you will determine the percentage by mass of iron in **FA 1**, an unknown compound. You will first prepare a solution of the compound and then carry out a titration using acidified potassium manganate(VII), KMnO_4 .



The end-point of the titration is when all the Fe^{2+} ions have been oxidised and so unreacted potassium manganate(VII) causes the colour of the solution to become a permanent pale pink.

FA 1 is a sample of the unknown compound.

FA 2 is $0.0100 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 3 is dilute sulfuric acid, H_2SO_4 .

(a) Method

Weighing the compound

- Weigh the sample of **FA 1** and its container.
- Tip the **FA 1** into the 250 cm^3 beaker.
- Reweigh the container including any residual **FA 1**.
- Record both your readings clearly in the space below.
- Calculate the mass of **FA 1** transferred into the beaker. Record the mass.

Preparing the solution

- Add approximately 200 cm^3 of distilled water to the beaker and stir until the **FA 1** has dissolved.
- Pour the contents carefully into the 250 cm^3 volumetric flask.
- Rinse the contents of the beaker with a little distilled water and add these washings to the flask.
- Fill the flask to the line with distilled water and shake thoroughly.
- Label this solution **FA 4**.

Titration

- Fill the burette with **FA 2**.
- Pipette 25.0 cm³ of **FA 4** into a conical flask.
- Use the 25 cm³ measuring cylinder to add 15 cm³ of **FA 3** to the conical flask.
- Add **FA 2** from the burette until the solution in the flask turns a permanent pink.
- Carry out a rough titration and record your burette readings in the space below.

rough titre = ... cm³

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

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

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

25.0 cm³ of **FA 4** 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 in the volume recorded in **(b)**.

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

(iii) Calculate the amount, in mol, of iron(II) ions in the weighed sample of **FA 1**.

amount of Fe^{2+} = ... mol [1]

(iv) Calculate the percentage by mass of iron in **FA 1**. Show your working.

percentage by mass of iron = ... % [2]

(d) A student carries out the same experiment as in **(a)**. The student receives a sample of **FA 1** in a container with a lid. The student records the initial mass of the container with its lid and the sample of **FA 1**. Then the student records the mass of the container with the residue but forgets to replace the lid.

How would this error alter the student's answer to **(c)(iv)**?
Explain your answer.

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

(e) State **two** assumptions that have been made in calculating the percentage by mass of iron in **FA 1** in **(c)(iv)**.

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

[Total: 17]

Question 2 starts on the next page.

- 2 In this experiment you will determine the percentage by mass of magnesium in a hydrated salt, $\text{MgX} \cdot 7\text{H}_2\text{O}$, where **X** represents the anion.

You will measure the loss of mass when a sample of the hydrated salt is heated to form the anhydrous salt.

FA 5 is a pure sample of $\text{MgX} \cdot 7\text{H}_2\text{O}$

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Add all of **FA 5** to the crucible.
- Reweigh the crucible with its lid and **FA 5**. Record the mass.
- Support the crucible in the pipe-clay triangle on top of the tripod.
- Heat the crucible with the lid on **gently** for about 1 minute.
- Remove the lid and then heat strongly for a further 4 minutes.
- Replace the lid and allow the crucible to cool for at least 5 minutes.

While the crucible is cooling you may wish to begin work on Question 3.

- When the crucible is cool enough to handle, reweigh the crucible with its lid and its contents. Record the mass.
- Calculate and record the mass of **FA 5** used.
- Calculate and record the mass of water lost.

I	
II	
III	
IV	
V	

[5]

(b) Calculations

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

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

- (ii) Calculate the percentage by mass of magnesium in **FA 5**. Show your working.

percentage by mass of Mg = ... % [2]

- (c) Suggest **two** assumptions that must be made for this experiment to give an accurate value of the percentage of Mg.

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

[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.

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

No additional tests should be attempted.

3 (a) FA 6 is an acidified aqueous solution of a salt which contains two cations and one anion, all of which are listed in the Qualitative analysis notes.

- (i) Select a reagent or reagents for use in tests to identify the two cations.
Record your observations.

[2]

- (ii) The anion in **FA 6** is either the sulfate ion, SO_4^{2-} , or the sulfite ion, SO_3^{2-} .
Select a reagent or reagents for use in tests to identify the anion.
Record your observations.

[2]

- (iii) Identify the ions present in **FA 6** and give their formulae.

The cations present in **FA 6** are and

The anion present in **FA 6** is

[2]

- (b) Carry out the tests and record your observations.
For each test use a 1 cm depth of **FA 6** in a test-tube.

<i>test</i>	<i>observations</i>
Test 1 Add a 1 cm depth of aqueous sodium sulfite, then	
add a 1 cm depth of dilute sulfuric acid. Rinse out this test-tube thoroughly.	
Test 2 Add a 1 cm depth of aqueous potassium iodide, then	
add a few drops of starch solution.	

[2]

- (c) **FA 7**, **FA 8** and **FA 9** are aqueous solutions of sodium salts. Each solution contains one of the following ions: CO_3^{2-} , Cl^- , Br^- .

You will identify which solution contains which ion.

- (i) Carry out the tests and record your observations.
For each test use a 1 cm depth of **FA 7**, **FA 8** or **FA 9** in a test-tube.

test	observations		
	FA 7	FA 8	FA 9
Add a few drops of aqueous silver nitrate, then			
add aqueous ammonia.			

[3]

- (ii) If your results are insufficient to identify which anion is present in each solution, carry out a further test. Record your test and observations.

[1]

- (iii) Identify which solution contains which ion.

The CO_3^{2-} ion is present in

The Cl^- ion is present in

The Br^- ion is present in

[1]

[Total: 13]

Qualitative analysis notes

1 Reactions of cations

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

2 Reactions of anions

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

3 Tests for gases

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

4 Tests for elements

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

Important values, constants and standards

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

The Periodic Table of Elements

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

lanthanoids

actinoids

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



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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

October/November 2022

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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

INFORMATION

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

Session

Laboratory

For Examiner's Use

1

2

3

Total

This document has **12** pages.

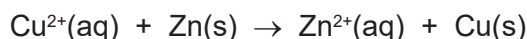
Quantitative analysis

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

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

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

- 1 You are to determine the enthalpy change for a metal displacement reaction using a known volume and concentration of copper(II) sulfate and an excess of powdered zinc.



FB 1 is 0.80 mol dm⁻³ copper(II) sulfate, CuSO₄.

FB 2 is zinc, Zn.

(a) Method

- Weigh the container with **FB 2**. Record the mass.
- Support the cup in the 250 cm³ beaker.
- Use the 50 cm³ measuring cylinder to transfer 30.0 cm³ of **FB 1** into the cup.
- Place the thermometer in the solution. Measure and record the initial temperature of the solution. This is the temperature at time zero, $t = 0$.
- Start timing and do not stop the clock until the whole experiment has been completed.
- Measure and record the temperature of the solution every half minute for 2 minutes.
- At time $t = 2\frac{1}{2}$ minutes tip all the **FB 2** into the solution and stir the mixture.
- Measure and record the temperature of the mixture at $t = 3$ minutes and every half minute until $t = 9$ minutes. Stir the mixture between thermometer readings.
- Weigh the container with any residue of **FB 2**. Record the mass.
- Calculate and record the mass of **FB 2** added to the solution.

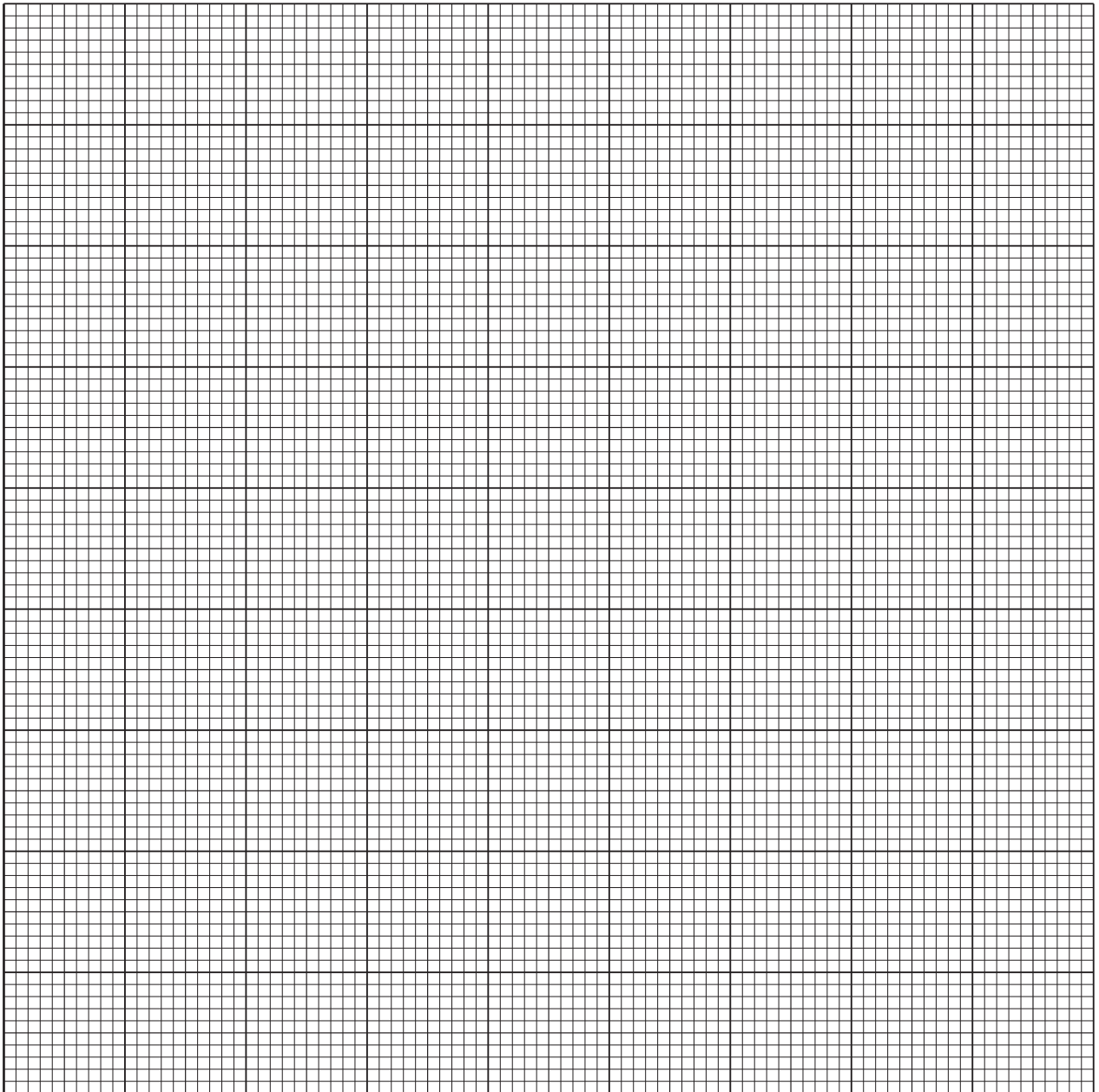
Results

time/minutes	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4
temperature/°C									

I	
II	
III	
IV	

time/minutes	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{2}$	9
temperature/°C										

[4]



- (b) (i) Plot a graph of temperature on the y-axis against time on the x-axis on the grid. The scale for temperature should extend 5°C above your highest recorded temperature. You will use this graph to determine the theoretical maximum temperature rise at $2\frac{1}{2}$ minutes. [3]
- (ii) Draw two lines of best fit through the points on your graph. The first line should be for the temperature before adding **FB 2** and the second for the cooling of the mixture.

Extrapolate the two lines to $2\frac{1}{2}$ minutes. Draw a vertical line at $2\frac{1}{2}$ minutes. Determine the theoretical rise in temperature at this time.

theoretical rise in temperature at $2\frac{1}{2}$ minutes = ... $^{\circ}\text{C}$ [2]

- 2 Many metal carbonates, such as copper(II) carbonate, exist as basic carbonates. These are a combination of the metal carbonate and a base of the metal.

A bottle is labelled copper(II) carbonate, CuCO_3 . You will carry out a gravimetric experiment to see whether the formula given is correct.



FB 3 is copper(II) carbonate and may have the formula CuCO_3 .

(a) Method

- Weigh a crucible with its lid. Record the mass.
- Add 1.50–1.80 g of **FB 3** to the crucible.
- Weigh the crucible and lid with **FB 3**. Record the mass.
- Place the crucible on the pipe-clay triangle. Heat the crucible, with the lid on, gently for approximately 1 minute and then strongly for another minute.
- Remove the lid. Heat the crucible strongly for about 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

While the crucible is cooling you may wish to begin work on Question 3.

- Reweigh the crucible and contents with its lid. Record the mass.
- Calculate and record the mass of **FB 3** added to the crucible.
- Calculate and record the mass of the residue obtained.

Keep the residue for use in 2(d).

Results

I	
II	
III	
IV	

[4]

(b) Calculations

- (i)**
- The residue obtained in
- (a)**
- is copper(II) oxide.

Calculate the amount, in mol, of copper(II) oxide formed on heating.

amount of CuO = ... mol [1]

- (ii)**
- Calculate the mass lost on heating the copper carbonate.

mass lost = ... g

Assuming the formula for **FB 3** is CuCO_3 , calculate the amount, in mol, of carbon dioxide lost on heating.

amount of CO_2 = ... mol
[1]

- (iii)**
- Use your answers to
- (b)(i)**
- and
- (b)(ii)**
- to explain whether the formula of
- FB 3**
- is
- CuCO_3
- .

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

- (c)**
- Another bottle of copper(II) carbonate was labelled basic copper(II) carbonate but part of the label giving the formula had been torn and only showed '
- $\text{CuCO}_3 \cdot \text{Cu} \dots$
- '.

Suggest a formula for basic copper(II) carbonate.

One possible formula for basic copper(II) carbonate is [1]

- (d) (i)**
- It is possible that
- FB 3**
- did not decompose fully on heating in
- (a)**
- .

Explain how you would change the method used to ensure decomposition was complete.

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

- (ii)**
- Select a reagent to use to test whether your sample of
- FB 3**
- has decomposed completely.

reagent

Carry out your test on the residue from **(a)**. Record your observations. State your conclusion.

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

[Total: 11]

Qualitative analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

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

(a) **FB 4** is an aqueous solution containing one cation and one anion, both of which are listed in the Qualitative analysis notes.

FB 5 is an aqueous solution of an organic compound which contains a functional group which is one of an alcohol, an aldehyde or a carboxylic acid.

- (i)** For each test use a 1 cm depth of **FB 4** in a test-tube. Record all your observations.

<i>test</i>	<i>observations</i>
Test 1 Add aqueous ammonia, then	
add aqueous EDTA.	
Test 2 Add a 2 cm depth of aqueous EDTA, then	
add a few drops of aqueous sodium hydroxide, then	
add a 1 cm depth of FB 5 and place the test-tube in the hot water bath.	

<i>test</i>	<i>observations</i>
Test 3 Add a strip of magnesium ribbon and leave the test-tube for 1 minute.	

[5]

- (ii) The anion in **FB 4** is either a halide or an anion containing sulfur. Select reagents to positively identify the anion.

Carry out your tests and record the reagents used and your observations in a suitable form below.

[3]

- (iii) Identify the compound in **FB 4** from your observations.

The formula of **FB 4** is

[1]

- (iv) Give an ionic equation for a reaction in **Test 3**. Include state symbols.

..... [1]

- (b) Reheat your water bath to boiling then switch off your Bunsen burner.

Prepare Tollens' solution for use in **Test 1** as follows:

Place a $\frac{1}{2}$ cm depth of aqueous silver nitrate in a test-tube. Add 1 or 2 drops of aqueous sodium hydroxide to form a brown precipitate. Shake the tube then add aqueous ammonia dropwise with shaking until the precipitate just dissolves.

When you have completed **Test 1** pour the contents of the test-tube down the sink with plenty of water and rinse the test-tube.

- (i) Use a 1 cm depth of **FB 5** in a test-tube for each of the following tests.

<i>test</i>	<i>observations</i>
Test 1 Add a 1 cm depth of Tollens' solution and place the test-tube in the hot water bath.	
Test 2 Add 1 or 2 drops of acidified aqueous potassium manganate(VII) and place the test-tube in the hot water bath.	
Test 3 Add a 1 cm depth of aqueous sodium carbonate.	

[3]

- (ii) **FB 5** contains a functional group which is either an alcohol, an aldehyde or a carboxylic acid.

State which functional group is present. Explain your answer.

.....

..... [1]

[Total: 14]

Qualitative analysis notes

1 Reactions of cations

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

2 Reactions of anions

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

3 Tests for gases

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

4 Tests for elements

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

Important values, constants and standards

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

The Periodic Table of Elements

Group																											
1	2											1		13	14	15	16	17	18								
		Key																2									
		atomic number atomic symbol name relative atomic mass																									
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	86										
Cs caesium 132.9	Ba barium 137.3			Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	Rn radon —										
87	88	89–103 actinoids		104	105	106	107	108	109	110	111	112	113	114	115	116	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 lanthanum 138.9	Ce cerium 140.1	Pr praseodymium 140.9	Nd neodymium 144.4	Pm promethium —	Sm samarium 150.4	Eu europium 152.0	Gd gadolinium 157.3	Tb terbium 158.9	Dy dysprosium 162.5	Ho holmium 164.9	Er erbium 167.3	Tm thulium 168.9	Yb ytterbium 173.1	Lu lutetium 175.0
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac actinium —	Th thorium 232.0	Pa protactinium 231.0	U uranium 238.0	Np neptunium —	Pu plutonium —	Am americium —	Cm curium —	Bk berkelium —	Cf californium —	Es einsteinium —	Fm fermium —	Md mendelevium —	No nobelium —	Lr lawrencium —



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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

October/November 2022

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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

INFORMATION

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

Session

Laboratory

For Examiner's Use

1

2

3

Total

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



Quantitative analysis

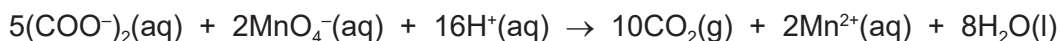
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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 Group 1 elements form salts with ethanedioic acid. These salts are ethanedioates and have the formula $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$, where **M** is the Group 1 metal.

Ethanedioate ions react with manganate(VII) ions as shown.



You will determine which metal is present in $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$ by titrating a solution of this salt with manganate(VII) ions.

FA 1 is 10.14 g dm^{-3} aqueous hydrated ethanedioate of metal **M**, $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$.

FA 2 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FA 3 is 1 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** into 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.
- During titrations, add **FA 2**, **slowly at first**, until a permanent pale pink colour is formed. The pink colour on initial addition may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70°C . If the brown colour disappears, continue with the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- 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 accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all your burette readings and the volume of **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, calculate a suitable mean value to 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 ethanedioate ions that reacted with the manganate(VII) ions in **(c)(ii)**.

amount of $(\text{COO}^-)_2$ = ... mol

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

concentration of $(\text{COO}^-)_2$ = ... mol dm^{-3} [1]

- (iv) Calculate the relative formula mass, M_r , of the hydrated ethanedioate, $(\text{COOM})_2 \cdot 2\text{H}_2\text{O}$.

M_r = ... [1]

- (v) Identify **M**. Show your working.

M is [2]

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

.....
 [1]

[Total: 15]

Question 2 starts on the next page.

- 2 Hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, can lose its water of crystallisation to form anhydrous copper(II) sulfate.

The enthalpy change for the dehydration of hydrated copper(II) sulfate is shown in the equation.



You will carry out experiments to determine the enthalpy changes for the solution of hydrated and anhydrous copper(II) sulfate and then use Hess's law to determine the enthalpy change of dehydration.

FA 4 is hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

FA 5 is anhydrous copper(II) sulfate, CuSO_4 .

(a) Determination of the enthalpy change of solution of hydrated copper(II) sulfate.

Method

- Weigh the container with **FA 4**. Record the mass.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 4** into the water and stir until the solid dissolves.
- Measure and record the lowest temperature reached.
- Rinse and dry the cup ready for the next experiment.
- Weigh the container with any residual **FA 4**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 4** used.

Results

[2]

(b) Calculations

- (i) Calculate the energy change during this reaction.

energy change = ... J [1]

- (ii) Calculate the amount, in mol, of hydrated copper(II) sulfate, **FA 4**, used in the experiment. Show your working.

amount of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ = ... mol [1]

- (iii) Calculate the enthalpy change, in kJ mol^{-1} , when 1.00 mol of hydrated copper(II) sulfate dissolves in water. This is the enthalpy of solution.

enthalpy change of solution = ... kJ mol⁻¹ [1]

sign value

- Weigh the container with **FA 5**. Record the mass.
- Support the cup in the 250 cm³ beaker.
- Use the measuring cylinder to transfer 25.0 cm³ of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 5** into the water and stir until the solid dissolves.
- Measure and record the highest temperature reached.
- Weigh the container with any residual **FA 5**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 5** used.

[1]

(i) Calculate the enthalpy change, in kJ mol^{-1} , for the enthalpy change of solution of anhydrous copper(II) sulfate.

9701/35/O/N/22

Qualitative analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

3 (a) FA 6 is an aqueous solution that contains one cation and two anions. The three ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests on **FA 6** and record your observations.

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FA 6 in a boiling tube add aqueous sodium hydroxide, then ----- heat gently.	
Test 2 To a 1 cm depth of FA 6 in a boiling tube add a 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Heat gently.	
Test 3 To a 1 cm depth of FA 6 in a test-tube add a few drops of hydrogen peroxide.	

[4]

- (ii) From your observations suggest **two** possible identities for the cation in **FA 6**.

possible cations: and [1]

- (iii) Suggest a test that would allow you to determine which of the cations you suggested in (a)(ii) is present in **FA 6**.

Carry out this test, record the result and hence identify the cation in **FA 6**.

test

result

The cation present is [2]

- (iv) From your observations in (a)(i) suggest **two** anions that could be present in **FA 6** and give their formulae.

possible anions: or [1]

- (v) Suggest an additional test that could be carried out to confirm the presence of **one** of the anions you suggested in (a)(iv).

Carry out this test, record the result and hence state the identity of the anion.

test

result

The anion present is [2]

- (b) Half fill the 250 cm³ beaker with water and heat to approximately 80 °C. Turn off the Bunsen burner. This will be your hot water bath.

FA 7 is an organic compound with an M_r between 40–57.

- (i) Carry out **Test 2** and **Test 3** on **FA 7** and record your observations. The result for **Test 1** is shown in the table.

<i>test</i>	<i>observations</i>
Test 1 Add a small piece of sodium.	no change
Test 2 To a 0.5 cm depth of aqueous iodine in a test-tube add aqueous sodium hydroxide dropwise until the yellow colour just disappears. Then add a few drops of FA 7 and shake the test-tube. If no change is seen, warm the test-tube in your hot water bath.	
Test 3 To a 1 cm depth of FA 7 in a test-tube add a few drops of acidified potassium manganate(VII). Warm the test-tube in your hot water bath.	

[2]

- (ii) Using the observations in (b)(i) suggest what can be deduced from each test about the functional groups present in **FA 7**.

Test 1

Test 2

Test 3

[2]

- (iii) Use your deductions in (b)(ii) to suggest the identity of **FA 7**.

FA 7 is [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	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 $\text{J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

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

lanthanoids

actinoids

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



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CHEMISTRY

9701/36

Paper 3 Advanced Practical Skills 2

October/November 2022

2 hours

You must answer on the question paper.

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

INSTRUCTIONS

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

INFORMATION

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

Session

Laboratory

For Examiner's Use

1	
2	
3	
Total	

This document has **12** pages.



Quantitative analysis

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

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

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

- 1** In this experiment you will determine the concentration of dilute hydrochloric acid by further diluting it and then titrating with aqueous potassium carbonate.

FB 1 is dilute hydrochloric acid, HCl . This acid will also be used in **Question 2**.

FB 2 is 8.46 g dm^{-3} anhydrous potassium carbonate, K_2CO_3 .

FB 3 is bromophenol blue indicator.

(a) Method

- Use the **10 cm³** pipette to transfer 10.0 cm^3 of **FB 1** into the volumetric flask.
- Make this solution up to 250 cm^3 using distilled water.
- Shake the volumetric flask and its contents thoroughly. Label this solution **FB 4**.
- Fill the burette with **FB 4**.
- Pipette **25.0 cm³** of **FB 2** into a conical flask.
- Add a few drops of **FB 3**.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

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

I	
II	
III	
IV	
V	
VI	
VII	

[7]

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

Show clearly how you obtained this value.

25.0 cm^3 of **FB 2** required cm^3 of **FB 4**. [1]

(c) Calculations

- (i) Give your answers to **(c)(ii)**, **(c)(iv)** and **(c)(v)** to the appropriate number of significant figures. [1]
- (ii) Use information on page 2 to calculate the amount, in mol, of potassium carbonate present in 25.0 cm³ of **FB 2**.

amount of K₂CO₃ = ... mol [1]

- (iii) Give the ionic equation for the reaction taking place in the titration in **(a)**. Include state symbols.

.....CO₃²⁻..... + ...H⁺..... → + ... [1]

- (iv) Calculate the concentration, in mol dm⁻³, of HCl in **FB 4**.

concentration of HCl in **FB 4** = ... mol dm⁻³ [1]

- (v) Calculate the concentration, in mol dm⁻³, of HCl in **FB 1**.

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

- (d) A student uses a solution containing 8.46 g dm⁻³ of **hydrated** potassium carbonate in the titration in **(a)** instead of **FB 2**.

State whether the student's titre would be larger or smaller than your titre. Explain your answer.

.....

 [1]

- (e) A student carries out the titration described in **(a)**. By mistake, a 25 cm³ pipette is used to transfer 25.0 cm³ of **FB 1** into a volumetric flask. The solution is made up to 250 cm³ with distilled water and labelled **FB 4**.

State how the subsequent experimental procedure could be modified so that the titre obtained in **(b)** is not altered by this mistake.

.....
 [1]

[Total: 15]

- 2 In this experiment you will determine the enthalpy change, ΔH , for the dehydration of hydrated sodium carbonate to anhydrous sodium carbonate.



You will determine the enthalpy changes for the reactions of anhydrous sodium carbonate and hydrated sodium carbonate with excess hydrochloric acid. Then you will use Hess's Law to calculate the enthalpy change for the reaction above.

FB 1 is dilute hydrochloric acid, HCl .

FB 5 is anhydrous sodium carbonate, Na_2CO_3 .

FB 6 is hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.

- (a) **Determination of the enthalpy change for the reaction of anhydrous sodium carbonate, FB 5, with excess hydrochloric acid.**

Method

- Support a cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 30.0 cm^3 of **FB 1** into the cup.
- Measure and record the initial temperature of the acid.
- Weigh the container with **FB 5**. Record the mass.
- **Slowly** add all **FB 5** to the acid in the cup.
Note that the reaction will be vigorous. Avoid inhaling any acid spray produced.
- Stir until the maximum temperature is reached. Measure and record this temperature.
- Weigh the container with any residual **FB 5**. Record the mass.
- Calculate and record the mass of **FB 5** used.
- Calculate and record the temperature change.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the energy change during this reaction.

energy change = ... J [1]

(ii) Calculate the amount, in mol, of anhydrous sodium carbonate, **FB 5**, used. Show your working.

amount of Na_2CO_3 = ... mol [1]

(iii) Calculate the enthalpy change, in kJ mol^{-1} , for the reaction between **FB 5** and **FB 1**, shown below.



enthalpy change for Na₂CO₃ = ... kJ mol⁻¹
 sign *value* [1]

(c) A student alters the method for the experiment in (a) and uses **FB 1** at half its original concentration but doubles the volume used.

The student suggests that the temperature change measured using their method would be more accurate than using the method in **(a)**.

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

..... [1]

- (d) **Determination of the enthalpy change for the reaction of hydrated sodium carbonate, FB 6, with excess hydrochloric acid, FB 1.**

Method

- Support the second cup in the 250 cm³ beaker.
- Use the measuring cylinder to transfer 30.0 cm³ of **FB 1** into the cup.
- Measure and record the initial temperature of the acid.
- Weigh the container with **FB 6**. Record the mass.
- Slowly add all the **FB 6** to the acid in the cup.
Note that the reaction will be vigorous. Avoid inhaling any acid spray produced.
- Stir until the minimum temperature is reached. Measure and record this temperature.
- Weigh the container with any residual **FB 6**. Record the mass.
- Calculate and record the mass of **FB 6** used.
- Calculate and record the temperature change.

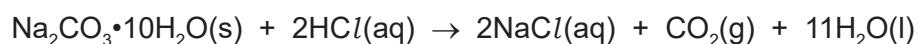
Results

I	
II	
III	

[3]

(e) Calculations

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



enthalpy change for $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} = \dots\dots\dots \text{kJ mol}^{-1}$
sign *value* [2]

- (ii) Use the enthalpy changes calculated in **(b)(iii)** and **(e)(i)** to calculate the enthalpy change, in kJ mol^{-1} , for dehydration of hydrated sodium carbonate.



enthalpy change for dehydration = $\dots\dots\dots \text{kJ mol}^{-1}$
sign *value* [1]

[Total: 14]

Qualitative analysis

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

Examples of observations include:

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

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

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

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

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

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

No additional tests should be attempted.

- 3 (a) FB 7** is an aqueous solution containing two anions listed in the Qualitative analysis notes. Neither of the anions contains nitrogen.

- (i) To a 1 cm depth of **FB 7** in a test-tube add a few drops of acidified aqueous potassium manganate(VII). Record your observations.

observations [1]

- (ii) Carry out further tests to identify both anions in **FB 7**.
Use a 1 cm depth of **FB 7** in a test-tube for each test.
Name the reagents you used and record the observations made in your tests.

The anions present in **FB 7** are and [4]

- (b) **FB 8** is a compound which contains one cation and one anion.
Both ions are listed in the Qualitative analysis notes.

- (i) Transfer a small spatula measure of **FB 8** into a hard-glass test-tube.
Heat gently, then strongly, until no further change occurs.
Allow the test-tube with the residue to cool for approximately 2 minutes.

Record **all** your observations.

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

- (ii) Pour a 2 cm depth of dilute hydrochloric acid into a test-tube.
Carefully, add a **small** spatula measure of **FB 8** to the acid.

Record your observations.
Retain the mixture obtained for use in (b)(iii).

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

- (iii) Add an equal volume of distilled water to the mixture obtained from (b)(ii). Mix thoroughly.
Carry out suitable tests to identify the cation in **FB 8**.
Use a 1 cm depth of the solution in a test-tube for each test you carry out.
Name the reagents you use.
Record your observations.

[2]

- (iv) From your observations in tests (b)(i), (b)(ii) and (b)(iii), deduce the formula of **FB 8**.

FB 8 is [1]

[Total: 11]

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
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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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Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
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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											13	14	15	16	17	18	
3 Li lithium 6.9	4 Be beryllium 9.0	Key																2 He helium 4.0
		atomic number atomic symbol name relative atomic mass																
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 oganeson —	

lanthanoids

actinoids

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