



Cambridge International AS & A Level

CANDIDATE
NAME

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CENTRE
NUMBER

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

May/June 2021

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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

Session	
Laboratory	

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.
- Notes for use in qualitative analysis are provided in the question paper.

For Examiner's Use	
1	
2	
3	
Total	

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

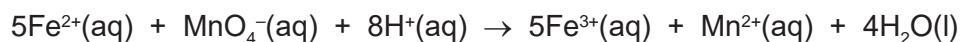


Quantitative analysis

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

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

- 1 Iron(II) sulfate crystals, $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$, contain water of crystallisation. You will carry out a titration to determine the value of x in the formula, where x is an integer. A solution containing a known mass of the crystals will be titrated with acidified aqueous potassium manganate(VII) of known concentration.



FA 1 contains 26.52 g dm^{-3} of hydrated iron(II) sulfate, $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

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

FA 3 is dilute 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 25 cm^3 measuring cylinder to transfer 25 cm^3 of **FA 3** into the same conical flask.
- Carry out 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 accuracy 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.

Keep FA 1 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a suitable 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 an appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 2** calculated in (b).

moles of $\text{KMnO}_4 = \dots\dots\dots$ mol [1]

- (iii) Calculate the number of moles of iron(II) sulfate present in 1.00 dm³ of **FA 1**.

moles of $\text{FeSO}_4 = \dots\dots\dots$ mol [1]

- (iv) Calculate the mass of iron(II) sulfate present in 1.00 dm³ of **FA 1**.

mass of $\text{FeSO}_4 = \dots\dots\dots$ g [1]

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

$x = \dots\dots\dots$ [2]

4

(d) Iron(II) sulfate in solution is readily oxidised by air to form iron(III) sulfate.

State the effect, on the value of x calculated in (c)(v), if some of your sample of **FA 1** had oxidised before you carried out the titration.
Explain your answer.

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

[Total: 16]

Question 2 starts on the next page.

- 2 In **Question 1** you used a titration method to determine the value of x in a hydrated salt. In **Question 2** you will use a gravimetric method. In this method a sample of solid is heated to remove the water of crystallisation.

You will carry out this method on a different hydrated compound, **FA 4**, with formula $MZ \cdot yH_2O$. In **FA 4** the value of y is an integer.



FA 4 is a hydrated compound, $MZ \cdot yH_2O$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Place between 2.40 g and 2.60 g of **FA 4** in the crucible and record its appearance below.
- Weigh the crucible, its lid and contents and record the mass.
- Without the lid, place the crucible on the pipe-clay triangle and heat gently for approximately one minute and record your observations.
- Then heat more strongly for approximately four minutes.
- Place the lid on the crucible and leave it to cool.

You may wish to start Question 3 while you are waiting for the crucible to cool.

- Weigh the crucible, its lid and contents and record the mass.
- Calculate and record the mass of **FA 4**, the mass of residue after heating and the mass of water lost.

Keep FA 4 for use in Question 3.

Results

appearance of **FA 4**

observations during heating for the first minute

.....

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the number of moles of water lost when your sample of $\text{MZ}\cdot y\text{H}_2\text{O}$ was heated.

moles of water = mol

The relative formula mass of the anhydrous compound MZ is 120.4.

Calculate the number of moles of MZ present in the residue.

moles of MZ = mol
[1]

- (ii) Use your answers from **(b)(i)** to calculate the value of y in **FA 4**, $\text{MZ}\cdot y\text{H}_2\text{O}$.
Show your working.

$y = \dots\dots\dots$ [1]

- (iii) State an assumption you made when calculating the value of y in the hydrated compound.

..... [1]

- (c) A student suggested that the experiment would be more accurate if the crucible had been heated with the lid on for the first minute.

State and explain whether you agree with the student.

.....

..... [1]

[Total: 8]

Qualitative analysis

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

At each stage of any test you are to record details of the following:

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

You should indicate clearly at what stage in a test a change occurs.

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

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

No additional tests for ions present should be attempted.

- 3 (a) Aqueous ammonium thiocyanate reacts with aqueous iron(III) ions to form an orange or red coloured compound. Iron(II) ions do not react in this way. The darker the orange or red colour, the more iron(III) ions are present in the solution.

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

<i>test</i>	<i>observations</i>
Test 1 Add a few drops of aqueous ammonium thiocyanate.	
Test 2 Add a few drops of aqueous sodium hydroxide and leave for at least two minutes, then	
----- add dilute sulfuric acid dropwise until there is no further change, then	
----- add a few drops of aqueous ammonium thiocyanate.	

[3]

- (ii) Suggest a reason for any difference in observation when you added aqueous ammonium thiocyanate in **Test 2** compared with **Test 1**.
Your answer should refer to the type of reaction that occurred in **Test 2**.

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

- (iii) The charge on the thiocyanate ion, SCN^- , is -1 .

Determine the formula of ammonium thiocyanate.

..... [1]

- (iv) A solution containing Fe^{2+} reacts with aqueous ammonia to form a green precipitate.

Write the ionic equation for this reaction.
Include state symbols.

..... [2]

(b) **FA 4** contains one cation and one anion, both of which are listed in the Qualitative Analysis Notes. The anion in **FA 4** contains sulfur.

(i) Carry out appropriate tests to allow you to identify the cation and anion in **FA 4**.

Record each test and your observations in a suitable form below.

[7]

(ii) Give the formula of the ions present in **FA 4**.

cation

anion

[1]

[Total: 16]

Qualitative analysis notes

1 Reactions of aqueous cations

ion	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 heating	–
barium, Ba ²⁺ (aq)	faint white ppt. is nearly always observed unless reagents are pure	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. with high [Ca ²⁺ (aq)]	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess	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

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)

3 Tests for gases

<i>gas</i>	<i>test and test result</i>
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

