

Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

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.

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

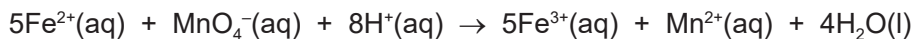


Quantitative analysis

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

Show 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 KMnO_4 = ... mol [1]

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

moles of FeSO_4 = ... mol [1]

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

mass of FeSO_4 = ... g [1]

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

x = ... [2]

(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 $\text{MZ} \cdot y\text{H}_2\text{O}$. In **FA 4** the value of y is an integer.



FA 4 is a hydrated compound, $\text{MZ} \cdot y\text{H}_2\text{O}$.

(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.

$y =$ [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

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	4													5	6	7	8	9	10	11	12	13	14	15	16	17	18										
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	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54		
K potassium 39.1	Ca calcium 40.1	Sc scandium 44.9	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	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 98.9	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	lanthanoids		57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
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 209.0	At astatine 210.0	Rn radon 222.0	Fr francium 223.0	Ra radium 226.0	actinoids		Rf rutherfordium 261.1	Db dubnium 262.1	Sg seaborgium 266.1	Bh bohrium 264.1	Hs hassium 277.1	Mt meitnerium 268.1	Ds darmstadtium 271.1	Rg roentgenium 272.1	Cn copernicium 285.1	Fl flerovium 289.1	Lv livermorium 293.1	Ts tennessine 294.1	Og oganesson 294.1		

lanthanoids														
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La lanthanum 138.9	Ce cerium 140.1	Pr praseodymium 140.9	Nd neodymium 144.4	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
actinoids														
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 —

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY

9701/32

Paper 3 Advanced Practical Skills 2

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.

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.

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

- 1 Washing soda consists of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$. When it is stored it loses some of its water of crystallisation to leave $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$. Since water has been lost x is no longer an integer.

You will carry out a titration to determine the value of x . You will titrate a solution of the sodium carbonate with hydrochloric acid.

The equation for the reaction is shown.



FB 1 is an aqueous solution containing 11.30 g dm^{-3} of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

FB 2 is 0.100 mol dm^{-3} hydrochloric acid, HCl .
bromophenol blue indicator

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- 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 your recorded results show the precision of your practical work.
- Record in a suitable form, in the space below, all of your burette readings and the volume of **FB 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a value for the volume of **FB 2** to be used in your calculations. Show clearly how you obtained this value.

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

(c) Calculations

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

moles of HCl = ... mol [1]

- (iii) Use the equation on page 2, and your answer to (c)(ii), to calculate the concentration, in mol dm⁻³, of Na₂CO₃·xH₂O present in **FB 1**.

concentration of Na₂CO₃·xH₂O = ... mol dm⁻³ [1]

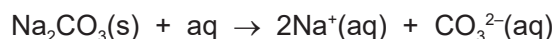
- (iv) Calculate the value of x in this sample of Na₂CO₃·xH₂O.

Show your working.

x = ... [3]

[Total: 14]

- 2 When anhydrous sodium carbonate dissolves in water the following reaction occurs.



The enthalpy change for this reaction is the enthalpy change of solution of anhydrous sodium carbonate. Its value is $-28.1 \text{ kJ mol}^{-1}$.

You will use this information to find the percentage purity of an impure sample of anhydrous sodium carbonate.

FB 3 is a sample of impure anhydrous sodium carbonate.

(a) Method

Experiment 1

- Weigh the cup and record the mass.
- Place between 1.9 g and 2.1 g of **FB 3** in the cup. Record the mass of the cup + **FB 3**.
- Calculate and record the mass of **FB 3** used.
- Support the cup in the beaker.
- Place 25.0 cm^3 of distilled water into the measuring cylinder. Measure and record the temperature of the water.
- Place the water in the cup and stir until all the solid dissolves.
- Place the thermometer in the solution and record the highest temperature reached. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Rinse the cup and shake dry ready to carry out **Experiment 2**.

Experiment 2

- Repeat the experiment using between 3.9 g and 4.1 g of **FB 3** and 25.0 cm^3 of water.
- Record your results in the same way as in **Experiment 1**.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

- (i) Use your results from **Experiment 1** to calculate the heat energy, in J, released when the **FB 3** dissolves.
(Assume 4.2 J of heat energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.)

heat energy = ... J [1]

- (ii) Use the information on page 4 to calculate the number of moles of anhydrous sodium carbonate needed to release the amount of energy in your answer to **(b)(i)**.

moles of Na₂CO₃ = ... mol [1]

- (iii) Calculate the mass of anhydrous sodium carbonate present in the number of moles in your answer to **(b)(ii)**.

mass of Na₂CO₃ = ... g [1]

- (iv) Use your answer to **(b)(iii)** to calculate the percentage purity of anhydrous sodium carbonate in **FB 3**.

percentage purity = ... [1]

- (c) In **(b)(iv)** you calculated the percentage purity of anhydrous sodium carbonate in **FB 3**.

What did you assume about the impurity present?

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

- (d) You carried out two experiments to measure the temperature change when anhydrous sodium carbonate was dissolved in water.

Complete the sentence below to explain which of these experiments was more accurate.

Your answer should not make reference to the fact that different masses of sodium carbonate were used.

Experiment was more accurate because
.....
..... . [1]

[Total: 11]

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) FB 4 and FB 5 each contain one cation and one anion from those listed in the Qualitative Analysis Notes.

Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>	
	FB 4	FB 5
Test 1 Heat a spatula measure of solid in a hard-glass test-tube gently at first and then more strongly, then		
----- leave the tube to cool.		
Test 2 To a small spatula measure of solid in a boiling tube add a 2 cm depth of dilute sulfuric acid.		

[5]

- (b) **FB 6** is a solution prepared by reacting **FB 4** with dilute sulfuric acid.
FB 7 is a solution prepared by reacting **FB 5** with dilute sulfuric acid.
 In each test use a 1 cm depth of **FB 6** or **FB 7** in a test-tube. Carry out the tests and record your observations.

test	observations	
	FB 6	FB 7
Test 1 Add a 1 cm depth of aqueous edta.		
Test 2 Add aqueous sodium hydroxide until no further reaction occurs.		
Test 3 Add aqueous ammonia until no further reaction occurs.		
Test 4 Add a 1 cm length of magnesium ribbon and leave to stand for a few minutes.		
Test 5 Add a 2 cm depth of aqueous potassium iodide, then		
add a few drops of starch indicator.		
Test 6 Add concentrated hydrochloric acid (CARE) drop by drop until no further change is seen. Wash the test-tube thoroughly with plenty of water once your observations are complete.		

[7]

- (c) Complete the table with the formula of each cation and each anion in **FB 4** and **FB 5**. If you are unable to identify an ion write 'unknown'.

	FB 4	FB 5
cation		
anion		

[2]

- (d) Write the ionic equation for the reaction between **FB 6** and magnesium. Include state symbols.

..... [1]

[Total: 15]

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

The Periodic Table of Elements

Group																				
1	2	Key												13	14	15	16	17	18	
		1 H hydrogen 1.0																		
3 Li lithium 6.9	4 Be beryllium 9.0	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	
11 Na sodium 23.0	12 Mg magnesium 24.3													13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9	
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8			
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3			
55 Cs caesium 132.9	56 Ba barium 137.3	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 —	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 —	114 Fl flerovium —	116 Lv livermorium —	—			—		

lanthanoids														
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La lanthanum 138.9	Ce cerium 140.1	Pr praseodymium 140.9	Nd neodymium 144.4	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
actinoids														
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 —

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY

9701/33

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.

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages. 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.

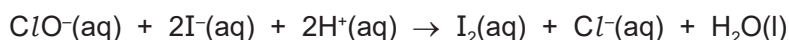
Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1** Bleach is made by reacting chlorine with a cold solution of sodium hydroxide. This reaction produces sodium chlorate(I), NaClO.

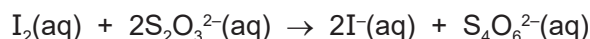


In this experiment you will determine the concentration of sodium chlorate(I) in a sample of bleach, **FA 1**.

To do this, you will react an acidified dilute solution of the bleach with iodide ions, I^- . This reaction produces iodine, I_2 .



The amount of iodine produced will then be determined by titration with thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$.



FA 1 is a solution of bleach.

FA 3 is dilute sulfuric acid, H_2SO_4 .

FA 4 is $0.500 \text{ mol dm}^{-3}$ potassium iodide, KI.

FA 5 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

starch indicator

(a) Method

Dilution

- Pipette 25.0 cm^3 of **FA 1** into the 250 cm^3 volumetric flask.
- Add distilled water to make 250 cm^3 of solution and shake the flask thoroughly.
- Label this flask **FA 2**.

Titration

- Fill a burette with **FA 5**.
- Rinse the pipette thoroughly with distilled water and then with a little **FA 2**.
- Pipette 25.0 cm^3 of **FA 2** into a conical flask.
- Use the measuring cylinder to add 20 cm^3 of **FA 3** to the conical flask.
- Use the measuring cylinder to add 15 cm^3 of **FA 4** to the conical flask. The solution will turn brown as iodine is produced.
- Add **FA 5** from the burette until the solution has turned yellow.
- Add 10 drops of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 5** from the burette until the blue-black colour just disappears. This is the end-point of the titration.
- Carry out a rough titration and record your burette readings in the space provided.

The rough titre = ... cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure that your recorded results show the precision of your practical work.
- Record in a suitable form in the space below all your burette readings and the volume of **FA 5** added in each accurate titration.

Keep FA 4 and FA 5 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a value for the volume of **FA 5** to be used in your calculations. Show clearly how you obtained this value.

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

(c) Calculations

- (i) Give your answers to **(c)(ii)** and **(c)(iii)** to the appropriate number of significant figures. [1]

- (ii) Use your answer to **(b)** and the relevant equation on page 2 to calculate the number of moles of iodine that formed when 25.0 cm³ of **FA 2** reacted with **FA 4**.

moles of I₂ = ... mol [1]

- (iii) Calculate the concentration of sodium chlorate(I) in **FA 1**.
Show your working.

concentration of NaClO = ... mol dm⁻³ [2]

- (d) (i)** In this method an excess of potassium iodide must be added to 25.0 cm³ of **FA 2**.

Use your answer to **(c)(ii)** to show by calculation that the potassium iodide is in excess.

[1]

- (ii)** A student carries out the same method but the concentration of the potassium iodide solution is not stated.

What change to the practical procedure could the student make to check that the potassium iodide is in excess?
Explain your answer.

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

[Total: 15]

- 2 In this experiment you will determine the value of x in the formula for hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$. In this formula x is an integer.

FA 6 is hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$.

(a) Method

- Support the cup in the 250 cm³ beaker.
- Rinse the measuring cylinder thoroughly with distilled water.
- Use the measuring cylinder to transfer 20.0 cm³ of distilled water into the cup.
- Measure and record the initial temperature of the water in the cup. Tilt the cup if necessary so that the bulb of the thermometer is fully covered.
- Weigh the stoppered container of **FA 6** and record the mass.
- Carefully add all the sample of **FA 6** to the water in the cup.
- Stir the mixture and record the minimum temperature.
- Reweigh the stoppered container and any residual **FA 6**. Record the mass.
- Calculate and record the mass of **FA 6** added to the water and the change in temperature.

I	
II	
III	
IV	

[4]

(b) Calculations

- (i) Calculate the heat energy change in the reaction.
(Assume that 4.2 J are required to change the temperature of 1.0 cm³ of solution by 1.0 °C.)

heat energy change = ... J
[1]

- (ii) Use your answer to (b)(i) to calculate the relative formula mass, M_r , of hydrated sodium thiosulfate.

You should assume that the enthalpy change of hydration, ΔH_{hyd} , for $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ is $+47.4 \text{ kJ mol}^{-1}$ under the conditions of your experiment.
Show your working.

$$M_r \text{ of } \text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O} = \dots\dots\dots [2]$$

- (iii) Use your answer to (b)(ii) to calculate the value of x in the formula $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$.

$$x = \dots\dots\dots [1]$$

- (c) A student repeats the experiment but adds 25.0 cm^3 of distilled water into the cup instead of 20.0 cm^3 . The student carries out the calculations based on adding 20.0 cm^3 .

What effect would this have on the student's answer to (b)(ii)?
Explain your answer.

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

[Total: 10]

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) FA 7 is a salt containing one cation and one anion, both of which are listed in the Qualitative Analysis Notes.

- (i) Transfer a small spatula measure of **FA 7** to a hard-glass test-tube and heat, gently at first and then more strongly.
Record all your observations.

.....

 [2]

- (ii) Place the remaining **FA 7** in the 100 cm³ beaker and dissolve in approximately 50 cm³ of distilled water.
Use a sample of this solution to test for the cation present in **FA 7**.
Record your tests and observations in the space below.

Keep the solution for use in (a)(iii).

[3]

- (iii) To a 1 cm depth of solution **FA 7** in a test-tube, add a few drops of aqueous silver nitrate. Record your observations.

..... [1]

- (iv) Suggest the ions present in **FA 7**.

cation anion [1]

- (b) **FA 8** is acidified aqueous iron(III) chloride, FeCl_3 .

Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FA 8 in a test-tube, add a 1 cm depth of FA 4 , then	
add starch indicator.	
Test 2 To a 1 cm depth of FA 8 in a test-tube, add a 1 cm depth of FA 5 . Allow to stand until there is no further change, then	
add a 1 cm depth of FA 4 , then	
add starch indicator.	

[3]

- (c) Half fill the 250 cm³ beaker with water. Place the beaker on a gauze supported on the tripod and heat the water to approximately 70 °C. Switch off the Bunsen burner. This will be used as a water-bath.

FA 9, FA 10 and FA 11 are each one of the following.

- 1.0 mol dm⁻³ hydrochloric acid, HCl
- 1.0 mol dm⁻³ methanoic acid, HCOOH
- 1.0 mol dm⁻³ sodium sulfite, Na₂SO₃

- (i) Carry out the following tests and record your observations. For each test use a 1 cm depth in a test-tube.

<i>test</i>	<i>observations</i>		
	FA 9	FA 10	FA 11
Test 1 Add a 1 cm strip of magnesium.			
Test 2 Add a few drops of aqueous acidified potassium manganate(VII). Place the test-tube in the hot water-bath.			

[3]

- (ii) Identify each of the solutions.

FA 9 is

FA 10 is

FA 11 is

[2]

[Total: 15]

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

The Periodic Table of Elements

Group																											
1	2													13	14	15	16	17	18								
		Key												1 H hydrogen 1.0													
3	4	atomic number atomic symbol name relative atomic mass												5	6	7	8	9	10	11	12	13	14	15	16	17	18
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									
11	12													13	14	15	16	17	18								
Na sodium 23.0	Mg magnesium 24.3													Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9								
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36										
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8										
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54										
Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3										
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86										
Cs caesium 132.9	Ba barium 137.3	lanthanoids	Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium	At astatine	Rn radon										
87	88	89–103	104	105	106	107	108	109	110	111	112							116									
Fr francium	Ra radium	actinoids	Rf rutherfordium	Db dubnium	Sg seaborgium	Bh bohrium	Hs hassium	Mt meitnerium	Ds darmstadtium	Rg roentgenium	Cn copernicium	Fl flerovium	Lv livermorium					–									

lanthanoids																	
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71			
La lanthanum 138.9	Ce cerium 140.1	Pr praseodymium 140.9	Nd neodymium 144.4	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			

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

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.

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.

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

- 1 You will carry out a titration to determine the concentration of a solution of potassium manganate(VII). You will react potassium manganate(VII) with excess acidified potassium iodide to produce iodine. You will then titrate the iodine with sodium thiosulfate.

FB 1 is hydrated sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

FB 3 is aqueous potassium manganate(VII), KMnO_4 .

FB 4 is 0.50 mol dm^{-3} potassium iodide, KI .

FB 5 is dilute sulfuric acid, H_2SO_4 .

starch indicator

(a) Method

Preparing a solution of FB 1

- Weigh the stoppered container of **FB 1**. Record the mass in the space below.
- Tip all the **FB 1** into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of **FB 1** used.
- Add approximately 100 cm^3 of distilled water to the **FB 1** in the beaker.
- Stir the mixture with a glass rod until all the **FB 1** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make the solution in the volumetric flask up to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of sodium thiosulfate is **FB 2**. Label the flask **FB 2**.

Titration

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 15 cm^3 of **FB 5** to the conical flask.
- Use the same measuring cylinder to add 10 cm^3 of **FB 4** to the conical flask.
- Perform a rough titration by adding **FB 2** from the burette to the conical flask until the solution is yellow. Then add several drops of starch indicator and continue the titration until the mixture in the flask becomes colourless. This is the end-point.

The rough titre is cm^3 .

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

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FB 2** to be used in your calculations.
Show clearly how you obtained this value.

The iodine produced by **FB 3** required cm³ of **FB 2**. [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii), (c)(iv) and (c)(v) to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of hydrated sodium thiosulfate, **FB 1**, that you weighed.

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

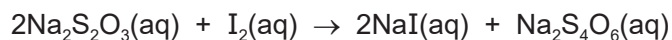
- (iii) Calculate the number of moles of sodium thiosulfate in the volume of **FB 2** calculated in (b).

moles of $\text{Na}_2\text{S}_2\text{O}_3$ = ... mol [1]

(iv) The reaction by which iodine is produced is shown.



During the titration, sodium thiosulfate reacts with the iodine produced.



Use your answer to (c)(iii) to calculate the concentration of KMnO_4 , in mol dm^{-3} , in **FB 3**.

concentration of KMnO_4 = ... mol dm^{-3} [1]

(v) Calculate the mass of KMnO_4 needed to prepare 1.00 dm^3 of **FB 3**. Show your working.

mass of KMnO_4 = ... g [1]

(d) (i) Solution **FB 3** was actually prepared by dissolving 3.16 g of KMnO_4 in 1.00 dm^3 of solution.

Show how you would use your answer to (c)(v) to calculate the overall percentage error in your experiment.

[1]

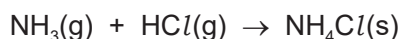
(ii) A student suggested that the percentage error in the experiment would be reduced by using a 10 cm^3 pipette to measure **FB 4**.

State whether the student is correct. Explain your answer.

.....
 [1]

[Total: 16]

- 2 You will determine the enthalpy change for the reaction of ammonia with hydrogen chloride.



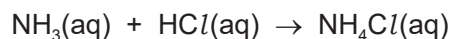
The procedure will involve two experiments.

FB 6 is 2.0 mol dm^{-3} aqueous ammonia, NH_3 .

FB 7 is 3.0 mol dm^{-3} hydrochloric acid, HCl .

FB 8 is ammonium chloride, NH_4Cl .

- (a) **Experiment 1: Determination of the enthalpy change of neutralisation of aqueous ammonia with hydrochloric acid**



(i)

- Support a cup in the beaker.
- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of **FB 6** into the cup.
- Measure and record the temperature of the solution in the cup.
- Rinse the 25 cm^3 measuring cylinder with water and then with a little **FB 7**.
- Use the 25 cm^3 measuring cylinder to add 25.0 cm^3 of **FB 7** to the **FB 6** in the cup.
- Stir the mixture.
- Measure and record the maximum temperature.
- Calculate and record the temperature rise.

[2]

- (ii) Calculate the energy released in your experiment.
(Assume that 4.2 J change the temperature of 1.0 cm^3 of solution by 1.0°C .)

energy released = ... J [1]

- (iii) Calculate the enthalpy change of reaction, ΔH_1 , in kJ mol^{-1} , for the neutralisation of $\text{NH}_3(\text{aq})$ with $\text{HCl}(\text{aq})$.
Show your working.

$\Delta H_1 = \dots\dots\dots \text{kJ mol}^{-1}$
sign value

[2]

(b) Experiment 2: Determination of the enthalpy change of solution of ammonium chloride



(i)

- Support a cup in the beaker.
- Rinse the 50 cm³ measuring cylinder with distilled water.
- Use the 50 cm³ measuring cylinder to transfer 30.0 cm³ of distilled water into the second cup.
- Measure and record the temperature of the water in the cup.
- Weigh the container with **FB 8**. Record the mass.
- Tip all of the **FB 8** into the water in the cup.
- Stir until all **FB 8** dissolves and record the minimum temperature observed.
- Calculate and record the temperature change.
- Weigh and record the mass of the container with any residual **FB 8**.
- Calculate and record the mass of **FB 8** used.

[3]

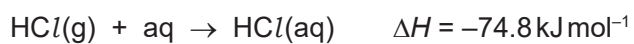
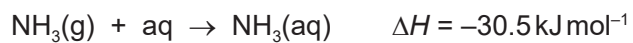
- (ii) Calculate the enthalpy change of solution, ΔH_2 , in kJ mol⁻¹, for **FB 8**, ammonium chloride. (Assume that 4.2 J change the temperature of 1.0 cm³ of solution by 1.0 °C.)

$$\Delta H_2 = \begin{array}{cc} \text{.....} & \text{.....} \end{array} \text{ kJ mol}^{-1}$$

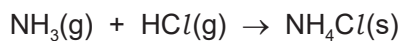
sign *value*

[2]

(c) The values for the enthalpy changes of solution of ammonia and hydrogen chloride are given.



From your answers to **(a)(iii)**, **(b)(ii)** and the data above, use Hess' Law to calculate the enthalpy change, ΔH_r , in kJ mol^{-1} , for the reaction below.


$$\Delta H_r = \text{.....} \text{ kJ mol}^{-1}$$

sign *value*

[1]

[Total: 11]

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) FB 9 contains one anion and one cation both of which are listed in the Qualitative Analysis Notes.

- (i)** Heat a small spatula measure of **FB 9** strongly in a hard-glass test-tube. Allow the test-tube and contents to cool. Record all your observations.

.....

 [2]

- (ii)** Add a small spatula measure of **FB 9** to a 3 cm depth of dilute sulfuric acid in a test-tube. Record all your observations.

.....

 [2]

- (iii)** If necessary, pour off the solution obtained in **(a)(ii)** in order to separate it from any remaining solid. Divide this solution into two equal portions in boiling tubes. Carry out the following tests and record your observations.

To the first boiling tube add aqueous sodium hydroxide.

.....

To the second boiling tube add aqueous ammonia.

.....
 [2]

(iv) Suggest the identity of **FB 9**.

FB 9 is

[1]

(b) **FB 10** contains one anion and one cation.

(i) Carry out the following tests and record your observations in the table.

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of aqueous copper(II) nitrate in a boiling tube, add an equal volume of FB 10 , then warm the mixture gently and carefully. Then add one piece of aluminium foil.	
Test 2 Warm a 1 cm depth of FB 10 gently in a boiling tube. Add one piece of aluminium foil. Allow the reaction to continue for one minute, then decant the solution into a boiling tube and add dilute hydrochloric acid until in excess.	
Test 3 To a 1 cm depth of aqueous chromium(III) sulfate in a test-tube, add FB 10 dropwise.	

[5]

(ii) Deduce the identity of the ions in **FB 10**.

If you were unable to deduce the identity of an ion, write 'unknown'.

cation	anion

[1]

[Total: 13]

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

The Periodic Table of Elements

Group																											
1	2													13	14	15	16	17	18								
		Key												1 H hydrogen 1.0													
3	4	atomic number atomic symbol name relative atomic mass												5	6	7	8	9	10	11	12	13	14	15	16	17	18
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	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	actinoids		104	105	106	107	108	109	110	111	112	114	116													
Fr francium	Ra radium			Rf rutherfordium	Db dubnium	Sg seaborgium	Bh bohrium	Hs hassium	Mt meitnerium	Ds darmstadtium	Rg roentgenium	Cn copernicium	Fl flerovium	Lv livermorium													

lanthanoids																	
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71			
La lanthanum 138.9	Ce cerium 140.1	Pr praseodymium 140.9	Nd neodymium 144.4	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			

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.



Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY

9701/35

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.

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.

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

- 1 In this experiment you will carry out a titration to determine the relative formula mass, M_r , of a monoprotic acid, HX.

FA 1 is HX, the monoprotic acid.

FA 2 is $0.0450 \text{ mol dm}^{-3}$ sodium carbonate, Na_2CO_3 .
methyl orange indicator

(a) Method

Preparing a solution of FA 1

- Weigh the empty 250 cm^3 beaker. Record the mass.
- Transfer all the **FA 1** into the beaker.
- Weigh the beaker and **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** used.
- Add approximately 100 cm^3 of distilled water to the **FA 1** in the beaker.
- Stir the mixture with a glass rod until all the **FA 1** has dissolved.
- Transfer this solution into the 250 cm^3 volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of HX is **FA 3**. Label the flask **FA 3**.

Results

Titration

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 2** into a conical flask.
- Add several drops of methyl orange indicator.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FA 3** to be used in your calculations.
Show clearly how you obtained this value.

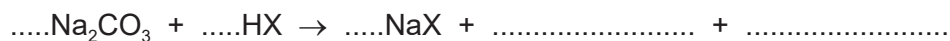
25.0 cm³ of **FA 2** required cm³ of **FA 3**. [1]

(c) **Calculations**

- (i) Calculate the number of moles of sodium carbonate present in the volume of **FA 2** used in each titration.

moles of Na₂CO₃ = ... mol [1]

- (ii) Give the equation for the reaction of **FA 2**, Na₂CO₃, with **FA 3**, HX.



Use your answer to (c)(i) to deduce the number of moles of HX present in the volume you calculated in (b).

moles of HX = ... mol [1]

- (iii) Use your answer to (c)(ii) and your data recorded on page 2 to calculate the relative formula mass, M_r , of HX.
Show your working.

M_r of HX = ... [2]

- (iv) One molecule of HX contains one nitrogen atom, three oxygen atoms, three hydrogen atoms and one atom of another element, **E**.
The identity of **E** can be found by calculation.

Show this calculation and identify **E**.

Element **E** is [1]

- (d) What is the error in a single reading for the balance that you used?

error = ... g

Calculate the maximum percentage error in the mass of **FA 1** that you recorded on page 2.

maximum percentage error = ... %
[1]

- (e) Suggest and carry out an experiment using aqueous silver nitrate to determine whether the compound AgX is soluble or insoluble in water.

method

.....

observations

conclusion

[2]

- (f) Suggest why the use of methyl orange indicator might give an inaccurate titration result.

.....

..... [1]

[Total: 18]

- 2 You will determine the percentage by mass of water of crystallisation in a hydrated salt by thermal decomposition. When a hydrated salt is heated it loses its water of crystallisation.

FA 4 is the hydrated salt.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Transfer 2.0–2.2 g of **FA 4** from the container into the crucible.
- Weigh the crucible, lid and **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** used.
- Place the crucible and contents on the pipe-clay triangle.
- Heat gently, with the lid on, for approximately 1 minute.
- Heat strongly, with the lid off, for a further 4 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.

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

- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, with the lid off, for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When it is cool, weigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass lost.

Keep FA 4 for use in Question 3.

Results

I	
II	
III	
IV	
V	

[5]

- (b) (i)** Calculate the percentage by mass of water of crystallisation in **FA 4**.

percentage by mass of H_2O in **FA 4** = ... % [1]

- (ii)** State what assumption you made about anhydrous **FA 4** in your calculation in **(b)(i)**.

.....
 [1]

[Total: 7]

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

Dissolve the remainder of the **FA 4** in approximately 20 cm³ of water in the 100 cm³ beaker. Use a 1 cm depth of this solution in a test-tube for each of the tests.

- (i)** The anion in **FA 4** is chloride.

State which reagents you would use to identify this ion conclusively.

.....

Use your reagents to test your solution of **FA 4**.
Record your observations.

.....

.....

.....

In what way are your observations **not** consistent with the expected results for chloride?

.....

.....

[3]

- (ii) Add an equal volume of dilute sulfuric acid to aqueous **FA 4**.

Record your observations and deduce the identity of the cation in **FA 4**.

observations

identity of cation

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

..... [2]

- (b) Use the conclusions in (a)(i) and (a)(ii) to calculate the relative formula mass of anhydrous **FA 4**.

M_r = ...

Use your results from **Question 2** to calculate the number of moles of water of crystallisation in one mole of hydrated **FA 4**.

moles of H_2O = ... [3]

- (c) **FA 5** contains one cation and one anion, both of which are listed in the Qualitative Analysis Notes.

- (i) Heat a small spatula measure of **FA 5** in a hard-glass test-tube.
Keep heating until no further change is observed.
Record **all** your observations.

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

- (ii) To a 1 cm depth of dilute sulfuric acid in a test-tube, add a small spatula measure of **FA 5**. Record all your observations.

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

- (iii) Place a small spatula measure of **FA 5** into a boiling tube. Add a 1 cm depth of aqueous sodium hydroxide and warm the mixture gently. Record your observations.

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

- (iv) From the results of your tests, deduce the chemical formula of **FA 5**.

FA 5 is [1]

[Total: 15]

BLANK PAGE

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

