



Cambridge International AS & A Level

CANDIDATE
NAME

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

October/November 2020

2 hours

You must answer on the question paper.

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

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.
- The insert contains printed text for use in your practical.

For Examiner's Use	
1	
2	
3	
Total	

This document has **16** pages. Blank pages are indicated.

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

- $$2\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{aq}) \rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + 2\text{I}^{-}(\text{aq})$$

starch indicator

Preparation of salt solution

- [illegible]

Titration

- Fill a burette with **FA 2**.
- Pipette 25.0 cm³ of **FA 3** into the conical flask.
- Add **FA 2** from the burette until the solution in the flask turns yellow.
- Add 10 drops of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 2** 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 below.

The rough titre is cm³.

- 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 **FA 2** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

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

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

(c) Calculations

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

(ii) Calculate the number of moles of iodine in 25.0 cm³ of **FA 3**.

moles of I₂ = ... mol [1]

(iii) Calculate the number of moles of thiosulfate ions in the volume recorded in **(b)**.

moles of S₂O₃²⁻ = ... mol

Hence calculate the number of moles of hydrated sodium thiosulfate in the mass weighed in **(a)**.

moles of Na₂S₂O₃•xH₂O = ... mol [1]

(iv) Calculate the value for x in the formula of hydrated sodium thiosulfate, Na₂S₂O₃•xH₂O. Show your working.

x = ... [3]

- (d) (i) State the maximum error in a single reading on the balance used in (a).

maximum error = $\pm$ g

Calculate the maximum percentage error in the mass of **FA 1** used in (a).
Show your working.

maximum percentage error = $\pm$ %
[1]

- (ii) Assume that the uncertainty in the mass of **FA 1** is the only source of error in your experiment.

Calculate the minimum value for the relative formula mass of **FA 1**.
Show your working.

minimum value for the relative formula mass of **FA 1** = ... [1]

- (e) A student prepares **FA 2** using anhydrous sodium thiosulfate salt and the same mass of salt that you used in (a).

State how the student's titre would compare with the average titre value you obtained in (b).
Explain your answer.

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

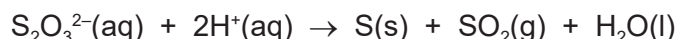
- (f) In many titrations it is usual to fill the burette with the solution of known concentration.

Suggest why this was not done in (a).

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

[Total: 19]

- 2 When a solution containing thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, is acidified the following reaction occurs.



The solid sulfur that is formed makes the mixture become cloudy. The rate of reaction can then be measured by timing how long it takes for the mixture to become too cloudy to see through.

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

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

FA 4 is 2.00 mol dm^{-3} hydrochloric acid, HCl .

FA 5 is a solution of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.
distilled water

(a) Method

Experiment 1

- Use the 50 cm^3 measuring cylinder to transfer 40.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of distilled water into the same beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse the beaker thoroughly.

Keep FA 5 for use in Question 3.

Record all your results in a table. You should include the volume of **FA 5**, the volume of distilled water, the reaction time and the rate of reaction for both experiments.

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

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

I	
II	
III	
IV	

[4]

- (b) A student suggested that the rate of the reaction is directly proportional to the concentration of the thiosulfate ions.

State whether your results support this suggestion.
Explain your answer.

.....

 [1]

- (c) The student's suggestion in (b) could be made more reliable by carrying out further experiments.

Prepare a table to show three further experiments you could carry out. Show clearly the volumes of **FA 4**, **FA 5** and distilled water that you would use in each of these experiments. Do not suggest a volume of **FA 5** that is greater than 40.0 cm³ or less than 20.0 cm³.

DO NOT CARRY OUT THESE ADDITIONAL EXPERIMENTS.

[2]

[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 6** is a salt containing one cation and one anion. The anion is listed in the Qualitative Analysis Notes.

Add all the sample of **FA 6** to the 100 cm³ beaker. Dissolve the solid in approximately 50 cm³ of distilled water.

Label this solution **FA 7**.

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

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FA 7 in a test-tube, add a 3 cm depth of aqueous silver nitrate.	
Pour approximately half the contents of the test-tube into a clean test-tube.	
Test 2 To the first test-tube add aqueous ammonia.	
Test 3 To the second test-tube add FA 5 , aqueous sodium thiosulfate.	

[2]

- (ii)** From the results of your tests in **(a)(i)** suggest which anion is present in **FA 6**.

..... [1]

- (iii) It is suggested that **FA 6** could be sodium sulfite, Na_2SO_3 , or sodium sulfate, Na_2SO_4 .

Carry out tests using solution **FA 7** in order to decide whether **FA 6** is sodium sulfite or sodium sulfate.

Record the reagents selected, the results of your tests and your conclusions in the space below.

FA 6 is sodium [2]

- (iv) Using your conclusion from (a)(iii), write an ionic equation for the reaction between silver nitrate and **FA 7**.
Include state symbols.

..... [1]

- (b) **FA 8** is a solution containing one of the cations listed in the Qualitative Analysis Notes.

- (i) 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 aqueous ammonia until there is no further change, then	
pour the contents into a boiling tube and add a few drops of aqueous hydrogen peroxide.	

[3]

- (ii) Identify the cation in **FA 8**.

cation = ... [1]

(iii) 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 aqueous potassium iodide, then	
add FA 5 , aqueous sodium thiosulfate.	

[2]

(iv) Explain your observations in (b)(iii).

.....

.....

..... [2]

[Total: 14]

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	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

57	La	lanthanum	138.9
58	Ce	cerium	140.1
59	Pr	praseodymium	140.9
60	Nd	neodymium	144.4
61	Pm	promethium	—
62	Sm	samarium	150.4
63	Eu	euroium	152.0
64	Gd	gadolinium	157.3
65	Tb	terbium	158.9
66	Dy	dysprosium	162.5
67	Ho	holmium	164.9
68	Er	erbium	167.3
69	Tm	thulium	168.9
70	Yb	ytterbium	173.1
71	Lu	lutetium	175.0
72	Hf	hafnium	178.5
73	Ta	tantalum	180.9
74	W	tungsten	183.8
75	Re	rhenium	186.2
76	Os	osmium	190.2
77	Ir	iridium	192.2
78	Pt	platinum	195.1
79	Au	gold	197.0
80	Hg	mercury	200.6
81	Tl	thallium	204.4
82	Pb	lead	207.2
83	Bi	bismuth	209.0
84	Po	polonium	—
85	At	astatine	—
86	Rn	radon	—
87	Fr	francium	—
88	Ra	radium	—
89	Ac	actinium	—
90	Th	thorium	232.0
91	Pa	protactinium	231.0
92	U	uranium	238.0
93	Np	neptunium	—
94	Pu	plutonium	—
95	Am	americium	—
96	Cm	curium	—
97	Bk	berkelium	—
98	Cf	californium	—
99	Es	einsteinium	—
100	Fm	fermium	—
101	Md	mendelevium	—
102	No	nobelium	—
103	Lr	lawrencium	—

actinoids

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CHEMISTRY

9701/33

Paper 3 Advanced Practical Skills 1

October/November 2020

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	
Total	

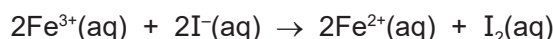
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Quantitative Analysis

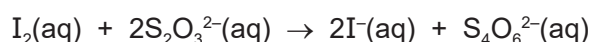
Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided on page 4.

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

- 1 In acidic solutions iron(III) ions are reduced by iodide ions to form iron(II) ions. The iodide ions are oxidised to iodine.



The rate of this reaction can be investigated by using starch indicator, which turns blue-black in the presence of iodine. Sodium thiosulfate is added to the reaction mixture to react with iodine as it is formed. The blue-black colour is seen when all the thiosulfate has reacted.



You will investigate how the rate of reaction is affected by changing the concentration of the iodide ions.

FA 1 is 0.0500 mol dm⁻³ potassium iodide, KI.

FA 2 is 0.0500 mol dm⁻³ acidified iron(III) chloride, FeCl₃.

FA 3 is 0.00500 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

FA 4 is starch indicator.

(a) Method

Prepare a table on page 4 for your results. You will need to include the volume of **FA 1**, volume of water, reaction time and rate of reaction for each of five experiments.

Experiment 1

- Fill the burette labelled **FA 1** with **FA 1**.
- Run 20.00 cm³ of **FA 1** into the 100 cm³ beaker.
- Use the 50 cm³ measuring cylinder to add the following to the same 100 cm³ beaker:
 - 20.0 cm³ of **FA 3**
 - 10.0 cm³ of **FA 4**.
- Use the 25 cm³ measuring cylinder to measure 10.0 cm³ of **FA 2**.
- Add this **FA 2** into the same 100 cm³ beaker and start timing immediately.
- Stir once and place the beaker on the white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Wash out the beaker and dry it with a paper towel.

Experiment 2

- Fill the second burette with distilled water.
- Run 10.00 cm³ of **FA 1** into the 100 cm³ beaker.
- Run 10.00 cm³ of distilled water into the beaker containing **FA 1**.
- Use the 50 cm³ measuring cylinder to add the following to the same 100 cm³ beaker:
 - 20.0 cm³ of **FA 3**
 - 10.0 cm³ of **FA 4**.
- Use the 25 cm³ measuring cylinder to measure 10.0 cm³ of **FA 2**.
- Add the **FA 2** to the same 100 cm³ beaker and start timing immediately.
- Stir once and place the beaker on the white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Wash out the beaker and dry it with a paper towel.

Experiments 3–5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of potassium iodide, **FA 1**.

The combined volume of **FA 1** and distilled water must always be 20.00 cm³.

Do not use a volume of **FA 1** that is less than 6.00 cm³.

Results

The rate of reaction can be calculated as shown:

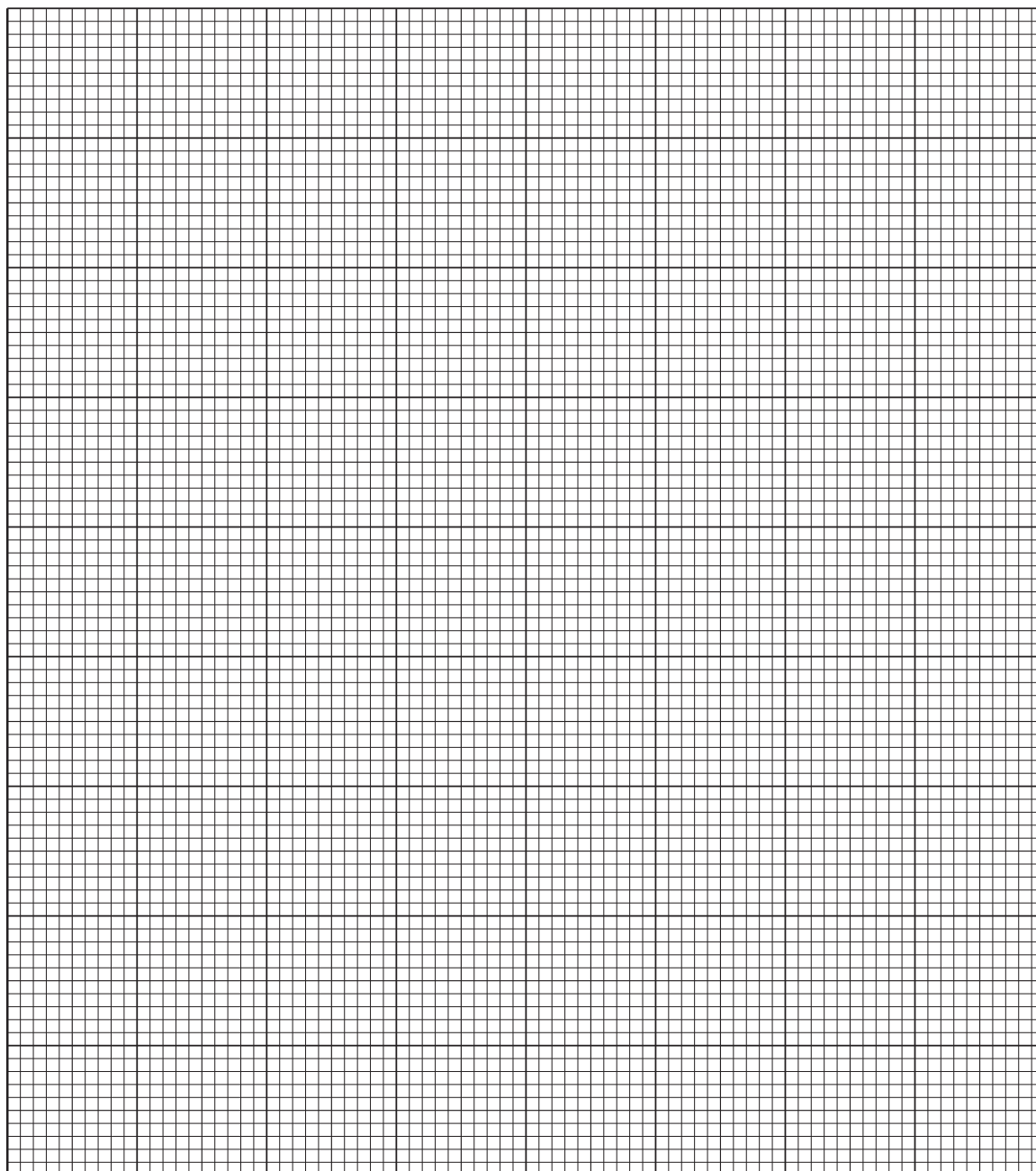
$$\text{rate} = \frac{1000}{\text{reaction time}}$$

I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	
X	

[10]

- (b) On the grid opposite, plot a graph of rate of reaction (y-axis) against volume of **FA 1** (x-axis). Include the origin, (0,0), in your scales. Circle any points you consider anomalous and draw a line of best fit.

[3]



- (c) Use your graph to calculate the time that the reaction would have taken if 5.00 cm^3 of FA 1 had been used. Show on the graph how you obtained your answer.

time = ... s [2]

- (d) (i) Using data from **Experiments 1** and **2**, show by calculation that the volume of aqueous potassium iodide, **FA 1**, used was directly proportional to the concentration of iodide ions.

[2]

- (ii) Explain, by referring to your graph or your table of results, how the rate of reaction is affected by an increase in the concentration of aqueous potassium iodide, **FA 1**.

.....

.....

.....

..... [2]

- (e) Thiosulfate ions can reduce iron(III) ions and also react with acid to form sulfur, sulfur dioxide and water.

- (i) Write an ionic equation for the reaction between thiosulfate ions and hydrogen ions in aqueous solution. Include state symbols.

..... [1]

- (ii) A student carries out the same investigation as in (a) but the solutions are mixed in a different order. The student places **FA 1** and an appropriate volume of distilled water in one beaker and all the other reactants in a second beaker. The student then transfers the mixture from the second beaker to the first and starts timing.

Tick the box for the statement you consider correct. Explain your answer.

The student's method is better than that in (a).

☐

The two methods are equally good.

☐

The student's method is not as good as that in (a).

☐

reason

.....

..... [1]

- (f) Another student investigates the effect of iron(III) concentration on the rate of this reaction. The student carries out another experiment, **Experiment 6**, and the rate is compared to that of **Experiment 2**. In **Experiment 2**, the volumes used were:

reagent	volume / cm ³
FA 1	10.00
FA 2	10.0
FA 3	20.0
FA 4	10.0
distilled water	10.00

- (i) Suggest the volumes the student could use for **Experiment 6**.

reagent	volume / cm ³
FA 1	
FA 2	
FA 3	
FA 4	
distilled water	

[2]

- (ii) This student records a time of 178 s for **Experiment 2**.

The rate of reaction is directly proportional to the concentration of iron(III) ions.

Suggest how long it would take the reaction mixture proposed for **Experiment 6** in (f)(i) to turn blue-black. Assume that **Experiment 6** is carried out at the same temperature as **Experiment 2**.

Do not carry out Experiment 6.

time = ... s [1]

[Total: 24]

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.

2 (a) FA 5 is a salt consisting of two ions both of which are listed in the Qualitative Analysis Notes.

- (i) Place a small spatula measure of **FA 5** into a hard-glass test-tube. Heat the tube gently at first and then more strongly. Record **all** your observations.

.....

 [3]

- (ii) **FA 6** is a sample of the residue obtained from **FA 5** after strong heating.

Place a small spatula measure of **FA 6** in a test-tube and add a 1 cm depth of aqueous hydrogen peroxide. Record your observations.

.....
 [2]

- (iii) Dissolve a spatula measure of **FA 5** in a 5 cm depth of distilled water in a boiling tube. Use separate 1 cm depths of this solution in test-tubes for the following tests. Record your observations.

Keep the remainder of FA 5(aq) for use in 2(b)(ii).

<i>test</i>	<i>observations</i>
Test 1 Add aqueous sodium hydroxide.	
Test 2 Add a 1 cm depth of aqueous hydrogen peroxide, then add aqueous sodium hydroxide.	

[2]

- (b) (i) **FA 7** is a solution of a different salt. The cation present in **FA 7** is not listed in the Qualitative Analysis Notes.

FA 5(aq) and **FA 7** each contain either a halide ion or an anion containing sulfur. These anions are listed in the Qualitative Analysis Notes.

For both of these anions, select reagents that you would use in order to carry out tests that give positive results.

Record the reagents and the ions for which they would test.

[2]

- (ii) Carry out both of your tests on **FA 5(aq)** and **FA 7** and record your results in the space below.

[3]

- (iii) Use your observations in (a) and (b)(ii) to identify the ions present in **FA 5** and **FA 7**. Write the formula of each ion in the table. If the tests you carry out do not allow you to identify any of the ions, write 'unknown'.

	FA 5	FA 7
cation		
anion		

[2]

- (iv) Suggest what you would observe if you added aqueous chlorine to separate portions of aqueous solutions of **FA 5** and **FA 7**.

Do not carry out this test.

aqueous chlorine and **FA 5**(aq)

aqueous chlorine and **FA 7**(aq)

[2]

[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	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		
		1 H hydrogen 1.0																		2 He helium 4.0	
		Key atomic number atomic symbol name relative atomic mass																			
3 Li lithium 6.9	4 Be beryllium 9.0													5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	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 —

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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

October/November 2020

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	
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Total	

This document has **16** pages. Blank pages are indicated.

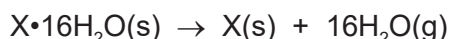
Quantitative Analysis

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 Many hydrated salts lose water of crystallisation when heated.
You will identify the metal in a hydrated salt by heating the salt until it becomes anhydrous.

The equation for the dehydration of the hydrated salt, $X \cdot 16H_2O$, is shown.



FB 1 is the hydrated salt, $X \cdot 16H_2O$.

(a) Method

- Weigh a crucible with its lid and record the mass.
- Add between 1.8 g and 2.0 g of **FB 1** to the crucible.
- Weigh the crucible and lid with **FB 1** and record the mass.
- Place the crucible on the pipe-clay triangle. Gently heat the crucible and contents for approximately two minutes with the lid on.
- Remove the lid. Then heat the crucible and contents strongly for approximately four minutes.
- Replace the lid and leave the crucible and residue to cool for at least five minutes.

While the crucible is cooling, you may wish to begin work on Question 2 or 3.

- Reweigh the crucible and contents with the lid on. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further two minutes.
- Replace the lid and leave the crucible and residue to cool for at least five minutes. Then reweigh the crucible and contents with the lid on. Record the mass.
- Calculate and record the mass of **FB 1** added to the crucible and the mass of residue obtained.

I	
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[5]

(b) Calculations

- (i) Calculate the number of moles of water of crystallisation lost during heating of **FB 1**.

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

- (ii) Use your answer to (b)(i) to calculate the number of moles of anhydrous residue, X, produced by the heating in (a).

moles of X produced = ... mol [1]

- (iii) Calculate the relative formula mass of X.

M_r of X = ... [1]

- (iv) X is the sulfate of a metal in Group 13 of the Periodic Table.

Calculate the relative atomic mass of the metal.
Show your working.

A_r of the metal = ... [1]

- (v) Use your answer to (b)(iv) to identify the metal present in X.

The metal is [1]

- (c) (i) Suggest why the crucible and contents were heated with the crucible lid on for the first two minutes of the experiment.

.....

 [1]

- (ii) Suggest whether the experiment would be more accurate if you reheated the crucible and contents strongly for a **third** time.
Explain your answer.

.....

 [1]

[Total: 12]

- 2 In this experiment, you will determine the concentration of an alkali. You will mix different volumes of acid with a fixed volume of alkali and measure the temperature rise that occurs each time. You will then determine the enthalpy change for the neutralisation of the acid with the alkali.

FB 2 is aqueous sodium hydroxide, NaOH.

FB 3 is 1.95 mol dm⁻³ sulfuric acid, H₂SO₄.

(a) Method

- Use the thermometer to measure and record the initial temperature of **FB 2**.

initial temperature of **FB 2** = ... °C

- Support a plastic cup in the 250 cm³ beaker.
- Fill one burette with **FB 3**. Label this burette **FB 3**.
- Fill the other burette with distilled water.

Experiment 1

- Use the 10 cm³ pipette to transfer 10.0 cm³ of **FB 2** into the plastic cup.
- Add 8.00 cm³ of distilled water from the burette into the plastic cup.
- Add 2.00 cm³ of **FB 3** from the burette into the plastic cup.
- Stir the mixture and measure the maximum temperature reached. (You may need to tilt the cup so that the bulb of the thermometer is completely immersed.) Record the maximum temperature.
- Empty, rinse and shake dry the plastic cup, ready for use in **Experiment 2**.
- Repeat this procedure to carry out experiments 2 to 5, using the volumes of **FB 2**, water and **FB 3** shown in the table. Record the maximum temperature reached in each experiment.

experiment	volume of FB 2 / cm ³	volume of H ₂ O / cm ³	volume of FB 3 / cm ³	maximum temperature / °C
1	10.0	8.00	2.00	
2	10.0	6.00	4.00	
3	10.0	4.00	6.00	
4	10.0	2.00	8.00	
5	10.0	0.00	10.00	
6	10.0			

I	
II	
III	
IV	
V	

Carry out **one** further experiment which will enable you to determine more precisely the minimum volume of **FB 3** that gives the highest maximum temperature. This is **Experiment 6**. Record the volumes of water and **FB 3** and the maximum temperature in the table above. [5]

- (b)** On the grid opposite, plot a graph of maximum temperature reached on the y-axis and volume of **FB 3** on the x-axis.
 Select a scale on the y-axis which includes a temperature 3.0 °C above the maximum temperature reached.
 Label any points you consider to be anomalous.



I	
II	
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IV	

Draw two **straight** lines of best fit on your graph. The first line is for increasing maximum temperature and the second after the maximum temperature was reached.

Extrapolate the two lines so that they intersect.

Use your graph to determine the volume of **FB 3** that reacts with 10.0 cm³ of **FB 2**.

volume of **FB 3** = ... cm³
[4]

- (c) (i) Calculate the change in energy when the volume of **FB 3** in (b) is neutralised by **FB 2**, sodium hydroxide.
Assume that 4.2 J of energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.

energy change = ... J [1]

- (ii) Calculate the number of moles of sulfuric acid in the volume of **FB 3** in (b).
(If you were unable to answer **2(b)**, use 5.70 cm³ as the volume of **FB 3**.)

moles of H₂SO₄ = ... mol [1]

- (iii) Calculate the enthalpy change of neutralisation, in kJ mol⁻¹, for 1.00 mol of H₂SO₄ reacting with **FB 2**.

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

- (iv) Write the equation for the neutralisation of **FB 3** with **FB 2**.
Include state symbols.

..... [1]

- (v) Use your answer to (c)(ii) and the information on page 4 to calculate the concentration, in mol dm^{-3} , of NaOH in **FB 2**.

concentration of NaOH in **FB 2** = ... mol dm^{-3} [1]

- (d) Apart from using a more accurate thermometer, better insulation or taking more readings, suggest **one** modification to the **procedure** which would make the value for the enthalpy change of neutralisation calculated in (c)(iii) more accurate.

.....

.....

..... [1]

[Total: 15]

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 The following information about the redox properties of some anions will be helpful.

<i>anion</i>	<i>property</i>
nitrite	easily oxidised
nitrate	cannot be oxidised
sulfite	easily oxidised
sulfate	cannot be oxidised

FB 4 and **FB 5** are solutions each containing one cation and one anion. Both anions are listed in the Qualitative Analysis Notes.

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

<i>test</i>	<i>observations</i>	
	FB 4	FB 5
Test 1 Add an equal volume of aqueous sodium carbonate.		
Test 2 Add aqueous ammonia.		
Test 3 Add a few drops of aqueous barium nitrate (or aqueous barium chloride).		
Test 4 Add an equal volume of dilute nitric acid. Allow to stand for one minute, then		
add a few drops of aqueous silver nitrate.		

[4]

- (b) Carry out the following tests in boiling tubes and record your observations in the table.
Use a 1 cm depth of **FB 4** or **FB 5** for each test.

<i>test</i>	<i>observations</i>	
	FB 4	FB 5
Test 1 Add aqueous sodium hydroxide, then		
warm the mixture gently and carefully , then		
add one piece of aluminium foil to the mixture.		

[3]

- (c) Using the information given at the start of the question, select **one** further test to enable you to identify the anions present in each of **FB 4** and **FB 5**.
- State the reagent(s) you will use for this test.
 - Explain why this test will enable you to identify the anions in **FB 4** and **FB 5**.
 - Carry out your test and record the observations.

reagent(s)

explanation

.....

observations

[3]

- (d) Write the formulae of the anions and cations present in **FB 4** and **FB 5**.
If the tests you carried out did not allow you to identify the ion, write 'unknown'.

FB 4: cation anion

FB 5: cation anion

[2]

- (e) Give the ionic equation for **one** precipitation reaction you observed when using **FB 4**.
Include state symbols.

..... [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	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						
														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	euroium	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

9701/35

Paper 3 Advanced Practical Skills 1

October/November 2020

2 hours

You must answer on the question paper.

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

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.
- The insert contains printed text for use in your practical.

For Examiner's Use	
1	
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Total	

This document has **16** pages. Blank pages are indicated.



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

- $$2\text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{aq}) \rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + 2\text{I}^{-}(\text{aq})$$

starch indicator

Preparation of salt solution

- [illegible]

Titration

- Fill a burette with **FA 2**.
- Pipette 25.0 cm³ of **FA 3** into the conical flask.
- Add **FA 2** from the burette until the solution in the flask turns yellow.
- Add 10 drops of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 2** 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 below.

The rough titre is cm³.

- 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 **FA 2** added in each accurate titration.

I	
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VIII	

[8]

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

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

(c) Calculations

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

(ii) Calculate the number of moles of iodine in 25.0 cm³ of **FA 3**.

moles of I₂ = ... mol [1]

(iii) Calculate the number of moles of thiosulfate ions in the volume recorded in **(b)**.

moles of S₂O₃²⁻ = ... mol

Hence calculate the number of moles of hydrated sodium thiosulfate in the mass weighed in **(a)**.

moles of Na₂S₂O₃•xH₂O = ... mol [1]

(iv) Calculate the value for x in the formula of hydrated sodium thiosulfate, Na₂S₂O₃•xH₂O. Show your working.

x = ... [3]

- (d) (i) State the maximum error in a single reading on the balance used in (a).

maximum error = $\pm$ g

Calculate the maximum percentage error in the mass of **FA 1** used in (a).
Show your working.

maximum percentage error = $\pm$ %
[1]

- (ii) Assume that the uncertainty in the mass of **FA 1** is the only source of error in your experiment.

Calculate the minimum value for the relative formula mass of **FA 1**.
Show your working.

minimum value for the relative formula mass of **FA 1** = ... [1]

- (e) A student prepares **FA 2** using anhydrous sodium thiosulfate salt and the same mass of salt that you used in (a).

State how the student's titre would compare with the average titre value you obtained in (b).
Explain your answer.

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

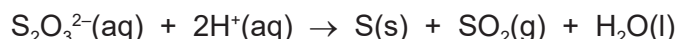
- (f) In many titrations it is usual to fill the burette with the solution of known concentration.

Suggest why this was not done in (a).

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

[Total: 19]

- 2 When a solution containing thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, is acidified the following reaction occurs.



The solid sulfur that is formed makes the mixture become cloudy. The rate of reaction can then be measured by timing how long it takes for the mixture to become too cloudy to see through.

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

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

FA 4 is 2.00 mol dm^{-3} hydrochloric acid, HCl .

FA 5 is a solution of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.
distilled water

(a) Method

Experiment 1

- Use the 50 cm^3 measuring cylinder to transfer 40.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready for use in **Experiment 2**.

Experiment 2

- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of **FA 5** into the 100 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 20.0 cm^3 of distilled water into the same beaker.
- Use the 25 cm^3 measuring cylinder to measure 20.0 cm^3 of **FA 4**.
- Add the 20.0 cm^3 of **FA 4** to **FA 5** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printed text on the insert from above through the mixture in the beaker.
- Note the time when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse the beaker thoroughly.

Keep FA 5 for use in Question 3.

Record all your results in a table. You should include the volume of **FA 5**, the volume of distilled water, the reaction time and the rate of reaction for both experiments.

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

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

I	
II	
III	
IV	

[4]

- (b) A student suggested that the rate of the reaction is directly proportional to the concentration of the thiosulfate ions.

State whether your results support this suggestion.
Explain your answer.

.....

 [1]

- (c) The student's suggestion in (b) could be made more reliable by carrying out further experiments.

Prepare a table to show three further experiments you could carry out. Show clearly the volumes of **FA 4**, **FA 5** and distilled water that you would use in each of these experiments. Do not suggest a volume of **FA 5** that is greater than 40.0 cm³ or less than 20.0 cm³.

DO NOT CARRY OUT THESE ADDITIONAL EXPERIMENTS.

[2]

[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 6** is a salt containing one cation and one anion. The anion is listed in the Qualitative Analysis Notes.

Add all the sample of **FA 6** to the 100 cm³ beaker. Dissolve the solid in approximately 50 cm³ of distilled water.

Label this solution **FA 7**.

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

<i>test</i>	<i>observations</i>
Test 1 To a 1 cm depth of FA 7 in a test-tube, add a 3 cm depth of aqueous silver nitrate.	
Pour approximately half the contents of the test-tube into a clean test-tube.	
Test 2 To the first test-tube add aqueous ammonia.	
Test 3 To the second test-tube add FA 5 , aqueous sodium thiosulfate.	

[2]

- (ii) From the results of your tests in (a)(i) suggest which anion is present in **FA 6**.

..... [1]

- (iii) It is suggested that **FA 6** could be sodium sulfite, Na_2SO_3 , or sodium sulfate, Na_2SO_4 .

Carry out tests using solution **FA 7** in order to decide whether **FA 6** is sodium sulfite or sodium sulfate.

Record the reagents selected, the results of your tests and your conclusions in the space below.

FA 6 is sodium [2]

- (iv) Using your conclusion from (a)(iii), write an ionic equation for the reaction between silver nitrate and **FA 7**.
Include state symbols.

..... [1]

- (b) **FA 8** is a solution containing one of the cations listed in the Qualitative Analysis Notes.

- (i) 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 aqueous ammonia until there is no further change, then	
pour the contents into a boiling tube and add a few drops of aqueous hydrogen peroxide.	

[3]

- (ii) Identify the cation in **FA 8**.

cation = ... [1]

(iii) 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 aqueous potassium iodide, then	
add FA 5 , aqueous sodium thiosulfate.	

[2]

(iv) Explain your observations in (b)(iii).

.....

.....

..... [2]

[Total: 14]

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	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														17	18				
		atomic number atomic symbol name relative atomic mass												1				2			
3	4																				
Li lithium 6.9	Be beryllium 9.0																	H hydrogen 1.0			
11	12																				
Na sodium 23.0	Mg magnesium 24.3																				
19	20																				
K potassium 39.1	Ca calcium 40.1																				
37	38																				
Rb rubidium 85.5	Sr strontium 87.6																				
55	56																				
Cs caesium 132.9	Ba barium 137.3																				
87	88																				
Fr francium —	Ra radium —																				
		3	4	5	6	7	8	9	10	11	12						13	14	15	16	
		21	22	23	24	25	26	27	28	29	30						5	6	7	8	9
		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						B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0
		39	40	41	42	43	44	45	46	47	48						13	14	15	16	17
		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						Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5
		71	72	73	74	75	76	77	78	79	80						31	32	33	34	35
		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						Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9
		89–103 actinoids	104	105	106	107	108	109	110	111	112						49	50	51	52	53
			Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —						In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9
																	81	82	83	84	85
																	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —



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CHEMISTRY

9701/36

Paper 3 Advanced Practical Skills 2

October/November 2020

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 Many salts occur in a hydrated form such as hydrated potassium carbonate, $\text{K}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, where x is an integer. You will determine the formula of a sample of hydrated potassium carbonate by adding it to an excess of hydrochloric acid and collecting the gas produced.



FB 1 is hydrated potassium carbonate, $\text{K}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

FB 2 is 0.50 mol dm^{-3} hydrochloric acid, HCl .

(a) Method

- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so the open end is in the water just above the base of the tub.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FB 2** into the flask labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Weigh the container with **FB 1** and record the mass.
- Remove the bung from the neck of the flask. Tip **all** of **FB 1** into the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents. Swirl the flask occasionally until no more gas is produced. Replace the flask in the clamp after each swirl.
- Measure and record the final volume of gas in the measuring cylinder.
- Weigh the container and any residual **FB 1** and record the mass.
- Calculate and record the mass of **FB 1** added.

Results

[3]

(b) Calculations

- (i) Calculate the number of moles of carbon dioxide collected in the measuring cylinder.
Assume 1 mol of gas occupies 24.0 dm^3 .

moles of $\text{CO}_2 = \dots\dots\dots \text{ mol}$ [1]

- (ii) Use your answer to **(b)(i)** and the information on page 2 to calculate the relative formula mass, M_r , of **FB 1**.

M_r of $\text{K}_2\text{CO}_3 \cdot x\text{H}_2\text{O} = \dots\dots\dots$ [1]

- (iii) Calculate the value of x in the formula of the hydrated potassium carbonate, $\text{K}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.
Show your working.

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

- (c) One of the errors associated with this method is caused by the solubility of carbon dioxide in water.

Suggest **two** modifications which could reduce this error.

modification 1

.....

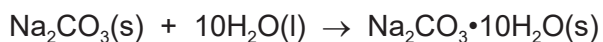
modification 2

.....

[2]

[Total: 9]

- 2 You will determine the enthalpy change of hydration of anhydrous sodium carbonate.



You will do this by measuring the changes in temperature when samples of anhydrous sodium carbonate and hydrated sodium carbonate are added separately to excess hydrochloric acid.

FB 3 is anhydrous sodium carbonate, Na_2CO_3 .

FB 4 is hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.

FB 5 is 2.00 mol dm^{-3} hydrochloric acid, HCl .

(a) Method

Experiment 1

- Weigh the container with **FB 3** and record the mass in the space below.
- Support the plastic cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FB 5** into the plastic cup.
- Place the thermometer in the solution and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature.
- Tip **all** of **FB 3** into the acid in the cup and stir the mixture.
- Record the highest or lowest temperature of the mixture.
- Calculate and record the change in temperature.
- Weigh the container with any residual **FB 3** and record the mass below.
- Calculate and record the mass of **FB 3** used.

Experiment 2

- Repeat the method given above using the second plastic cup, but this time use **FB 4** in place of **FB 3**.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (c) A student carrying out the experiment with anhydrous sodium carbonate, **FB 3**, could not find 2.00 mol dm^{-3} hydrochloric acid. The student used the same volume of 1.0 mol dm^{-3} sulfuric acid instead.

How would the change in temperature obtained by the student compare with the change that you obtained? Assume the same mass of **FB 3** was used.

Explain your answer.

.....

.....

..... [1]

[Total: 14]

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** **FB 6**, **FB 7** and **FB 8** are aqueous solutions of salts. Each contains one cation and one anion. All the anions and two of the cations are listed in the Qualitative Analysis Notes.

(a) (i) Use a 1 cm depth of each solution in a test-tube and record your observations in the table.

<i>test</i>	<i>observations</i>		
	FB 6	FB 7	FB 8
Test 1 Add aqueous ammonia.			
Test 2 Add dilute sulfuric acid.			
Test 3 Add a few drops of acidified aqueous potassium manganate(VII).			
Test 4 Add a 1 cm depth of FB 6 .			

[7]

- (ii)** Write an ionic equation for the reaction between **FB 6** and sulfuric acid. Include state symbols.

..... [2]

- (iii) Use your observations to identify the cations present in **FB 6**, **FB 7** and **FB 8**. Write the formula of each ion in the table. If the tests you carried out did not allow you to identify any of the ions, write 'unknown'.

	FB 6	FB 7	FB 8
cation			

[2]

- (b) (i) You will now investigate the identity of the anions present in **FB 7** and **FB 8**. Neither of the anions contains a nitrogen atom.
 Select reagents that you would need to use in order to carry out tests that give positive results for these ions.
 Record suitable reagents and the ions for which they would test.

[1]

- (ii) Carry out **all** of your tests on **FB 7** and **FB 8** and record your observations in the space below.

[4]

- (iii) Use your observations in (b)(ii) to identify the anions present in **FB 7** and **FB 8**. Write the formula of each ion in the table.

	FB 7	FB 8
anion		

[1]

[Total: 17]

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	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							2 He helium 4.0		
	atomic number atomic symbol name relative atomic mass																			
	3 Li lithium 6.9	4 Be beryllium 9.0									5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	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	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 —	114 Fl flerovium —	116 Lv livermorium —					

lanthanoids

actinoids

57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu
lanthanum	138.9	cerium	140.1	praseodymium	140.9	neodymium	144.4	promethium	—	samarium	150.4	euroium	152.0	gadolinium	157.3	terbium	158.9	dysprosium	162.5	holmium	164.9	erbium	167.3	thulium	168.9	ytterbium	173.1	lutetium	175.0
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr
actinium	227.0	thorium	232.0	protactinium	231.0	uranium	238.0	neptunium	—	plutonium	—	americium	—	curium	—	berkelium	—	californium	—	einsteinium	—	fermium	—	mendelevium	—	nobelium	—	lawrencium	—