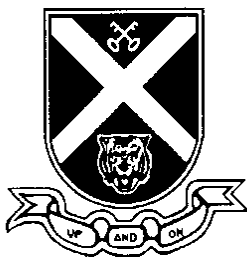


Name:		Class:	
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ST ANDREW'S JUNIOR COLLEGE



JC 2 PRELIMINARY EXAMINATION

CHEMISTRY

9729/04

Paper 4 Practical

13 Aug 2025

2 hours 30 minutes

Additional Materials: Qualitative Analysis Notes

READ THESE INSTRUCTIONS FIRST.

Write your name and class on all the work you hand in.

Give details of the practical shift and laboratory in the boxes provided above.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams or graphs.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in the brackets [] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	15
2	16
3	14
4	10
Total	55

1. Determination of the value of x in the hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$

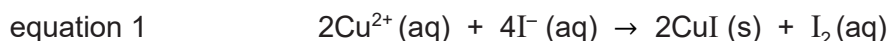
FA 1 is $0.150 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 2 is dilute sulfuric acid.

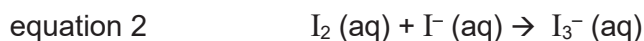
FA 3 is 1.00 mol dm^{-3} potassium iodide, KI.

FA 4 is a solution made by dissolving 32.5 g of $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ in 1.00 dm^3 of solution.
starch indicator

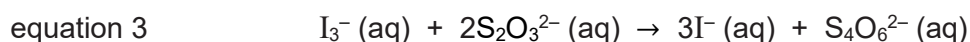
In this experiment you will perform titrations to determine the value of **x** in the formula for hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$, and its concentration in **FA 4**. You will first react a solution of Cu^{2+} ions with excess iodide ions, I^- . This reaction produces iodine as shown in equation 1.



I_2 has relatively low solubility in water. However, in the presence of excess I^- , the soluble triiodide ion, I_3^- is formed, as shown in equation 2.



The I_3^- ions formed may be titrated against a standard solution of $\text{Na}_2\text{S}_2\text{O}_3$ as shown in equation 3.

**(a) Procedure**

1. Fill the burette with **FA 1**.
2. Pipette 25.0 cm^3 of **FA 4** into a 250 cm^3 conical flask.
3. Use a 10 cm^3 measuring cylinder to transfer 10.0 cm^3 of **FA 2** to the same conical flask.
4. Use a second 10 cm^3 measuring cylinder to transfer 10.0 cm^3 of **FA 3** to the same conical flask. A white precipitate forms in a brown solution.
5. Add **FA 1** from the burette into this flask. Near the end-point, when the brown solution becomes pale, add about 10 drops of starch indicator.
6. Continue adding **FA 1** slowly. The end-point is reached when the **solution** first becomes colourless. The white precipitate remains.
7. Repeat steps 2 to 6 and step until consistent results are obtained.

Results☐

M1

☐

M2

☐

M3

☐

M4

[5]☐

M5

- (b) From your titrations, obtain a suitable volume of **FA 1** to be used in your calculations.

Show clearly how you obtained this volume

.

Volume of **FA 1** = cm³ **[1]**

☐

M6

[Turn Over]

- 1 (c) (i) Calculate the number of moles of $\text{S}_2\text{O}_3^{2-}$ in the volume of **FA 1** in (b).

Number of moles of $\text{S}_2\text{O}_3^{2-}$ in **FA 1** = **[1]**

☐

M7

- (ii) Calculate the number of moles of copper(II) ions in 25.0 cm^3 of **FA 4**.

Number of moles of Cu^{2+} in **FA 4** = **[1]**

☐

M8

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

[Ar: Cu, 63.5; S, 32.1; O, 16.0; H, 1.0]

x = **[1]**

☐

M9

- 1 (c) (iv) Blue vitriol solution is the concentrated form of **FA 4**.

FA 4 was prepared by diluting 10.0 cm^3 of blue vitriol solution to 250 cm^3 in a volumetric flask using deionised water.

Hence or otherwise, determine the concentration of Cu^{2+} in blue vitriol solution in mol dm^{-3} .

Concentration of Cu^{2+} in blue vitriol solution: mol dm^{-3}

[1]

☐

M10

- (d) A student performed a titration and obtained a titre volume of 30.50 cm^3 .
Calculate the maximum percentage error in the student's titre volume.

Maximum percentage error =

[1]

☐

M11

- 1 (e) A student suggests that the experiment could be made more accurate if the volume of **FA 3** was measured using a burette.

Suggest a reason why this change would not improve the accuracy of the experiment.

.....

[1]

☐

M12

- (f) A laboratory technician accidentally prepared **FA 4** by dissolving 32.5 g of hydrated copper(II) sulfate in 250 cm³ of water. Suggest how this mistake would affect the volume of **FA 1** required in the titration and the calculated value of **x** in CuSO₄.xH₂O.

Explain your answer.

.....

[2]

☐

M13

☐

M14

- (g) The formation of the white CuI precipitate can make it harder to determine the end-point of the titration. Suggest another method to measure the amount of iodine produced without using titration.

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[1]

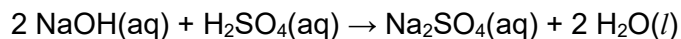
☐

M15

[Total: 15]

2 Determination of enthalpy change of neutralisation

You will determine the concentration of sulfuric acid by reacting with a known concentration of sodium hydroxide using a thermometric method. You are to also determine the enthalpy change of neutralisation per mole of water formed when these solutions react. The equation for the reaction is shown.



FA 2 is dilute sulfuric acid, H_2SO_4 .

FA 5 is 1.90 mol dm^{-3} sodium hydroxide, NaOH .

In this question, you will carry out a series of experiments where different volumes of **FA 5** and **FA 2** are mixed together.

You will determine the temperature change of the mixture, ΔT , of each experiment and then analyse your results graphically in order to determine the

- concentration of H_2SO_4 in **FA 2**
- maximum temperature change, ΔT_{max}
- value for the enthalpy change of neutralisation, ΔH_{neut}

(a) Procedure

1. Place a polystyrene cup inside a second polystyrene cup and place both cups in a glass beaker. The retort clamp provided may be used to clamp the beaker to prevent it from tipping.
2. Use a 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 5** into the polystyrene cup.
3. Place the lid with a hole in the centre on the cup and insert the thermometer through the lid. Stir the **FA 5** solution gently with the thermometer. Read and record the initial temperature of the solution of **FA 5** as T_{initial} .
4. Place 10.0 cm^3 of **FA 2** into another 50 cm^3 measuring cylinder.
5. Transfer the **FA 2** from the measuring cylinder into the polystyrene cup and close the lid. Stir the mixture gently with the thermometer.
6. Read and record the maximum temperature of the mixture, T_{max} , and the volume of **FA 2** added.
7. Rinse and dry the polystyrene cup and the thermometer with paper towel.

8. Repeat steps **1** to **6** using **5** different volumes of **FA 5**, mixing it with the appropriate volumes of **FA 2** to be used in each experiment such that the total volume of the reaction mixture is **60.0 cm³**.
9. Calculate ΔT for each experiment.

In an appropriate format in the space provided, prepare a table in which to record for each experiment

- all volumes, $V_{\text{FA 2}}$ and $V_{\text{FA 5}}$, to an appropriate level of precision
- all values of temperature, T_{initial} , T_{max} and ΔT to an appropriate level of precision.

Results

☐

M16

☐

M17

☐

M18

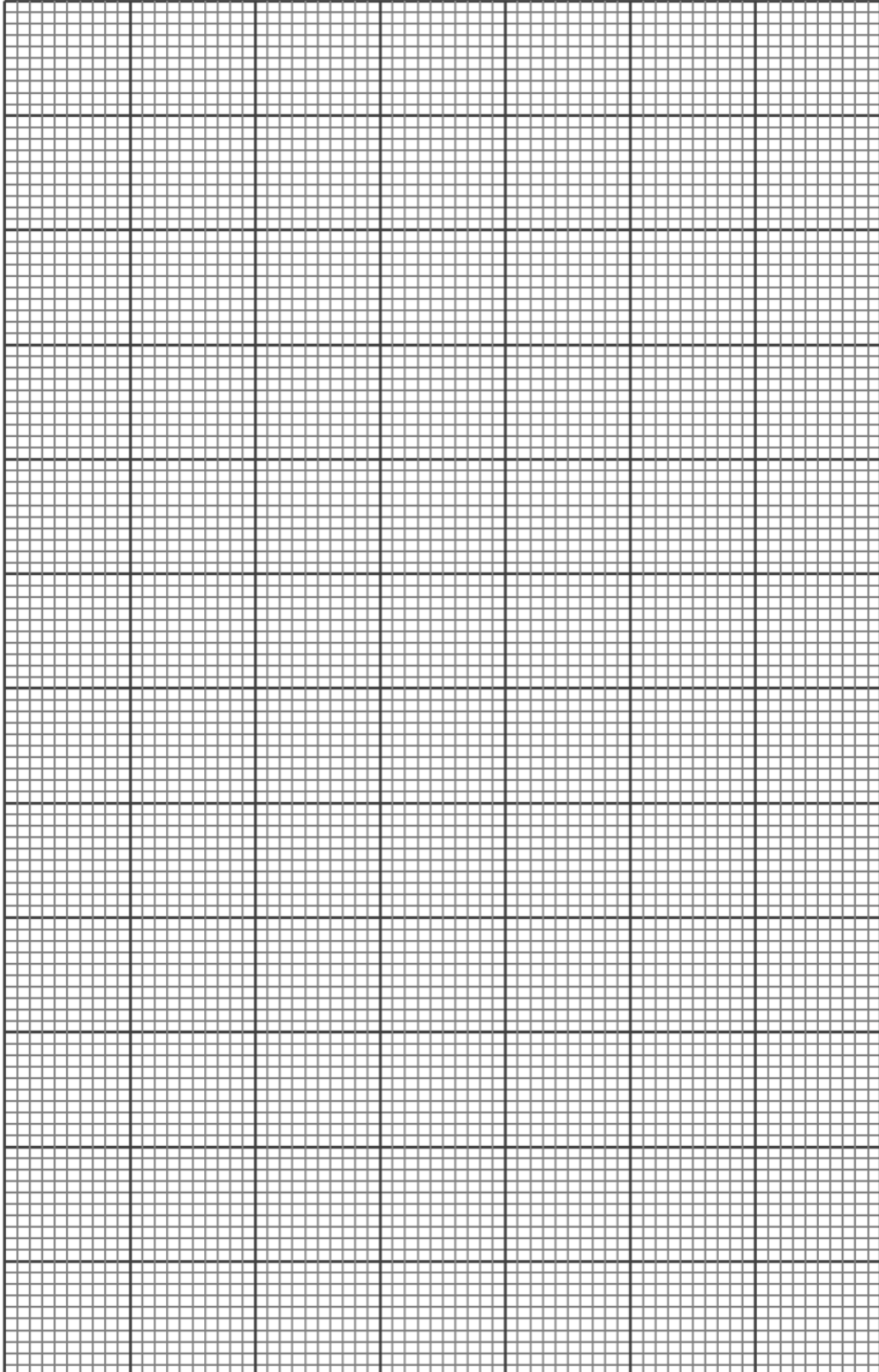
☐

M19

[4]

- (b) Plot a graph of ΔT against $V_{\text{FA 2}}$ added on the grid in Fig. 2.1. Your scale on the y-axis should allow for extrapolation above the highest temperature change recorded. Label any points you consider to be anomalous.

Draw two lines of best fit, one for the rise in temperature and one for after the maximum temperature has been reached. Extrapolate (extend) both lines until they intersect.

**Fig. 2.1****[3]**☐

M20

☐

M21

☐

M22

- 2 (c) (i) From Fig. 2.1, determine the maximum temperature change, ΔT_{\max} , and the V_{FA2} required to achieve this maximum temperature change.

Maximum temperature change, ΔT_{\max} : °C

☐

M23

Volume of **FA 2**, V_{FA2} : cm³ [2]

☐

M24

- (ii) Calculate the number of moles of **FA 5** reacted and hence, calculate the concentration of **FA 2**.

Number of moles of **FA 5** reacted:

☐

M25

Concentration of **FA2**: mol dm⁻³ [2]

☐

M26

- (iii) Calculate the heat change, q , at the point of neutralisation, in your experiment using the ΔT_{\max} value you deduced in (c)(i).

You should assume that the specific heat capacity of the solution is 4.18 J g⁻¹ K⁻¹, and that the density of the solution is 1.00 g cm⁻³.

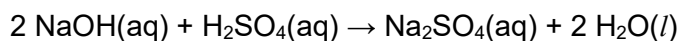
q : [1]

☐

M27

- 2 (c) (iv) Hence, calculate the enthalpy change of neutralisation, ΔH_{neut} , per mole of water formed.

The equation for the reaction is shown.



Include the sign of ΔH_{neut} in your answer.

$\Delta H_{\text{neut}} = \dots\dots\dots$

[2]

☐

M28

☐

M29

- (d) A student repeated the same experiment but used CH_3COOH instead of H_2SO_4 of the same concentration. Suggest and explain how the maximum temperature change will be affected.

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☐

M30

☐

M31

[2]

[Total: 16]

[Turn Over

3 In this question, you are provided with the following solutions.

- **FA 6** which contains two cations and one anion.
- **FA 7** which contains one cation and one anion.
- **FA 8** which contains an aqueous solution of an organic compound.

You will perform tests to identify the ions in **FA 6** and **FA 7**.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

If there is no observable change, write **no observable change**.

(a) (i) Carry out the following tests. Carefully record your observations in Table 3.1.

Table 3.1

Tests		Observations
1	Add 2 cm depth of FA 6 into a test-tube. Add aqueous sodium hydroxide until there is no further change. Filter the mixture into a clean test tube. To the filtrate, add 8 drops of dilute nitric acid, dropwise with shaking.	
2	Add 2 cm depth of FA 6 into a test-tube. Add aqueous ammonia until there is no further change. Filter the mixture into a clean test tube.	
3	Add 2 cm depth of FA 6 into a test-tube. Add dilute nitric acid until there is no further change.	

4	Add 2 cm depth of FA 6 into a test-tube. Add aqueous barium nitrate until there is no further change. Add dilute nitric acid until there is no further change.	
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[4]

- (a) (ii) Carry out the following tests. Carefully record your observations in Table 3.2.

Table 3.2

Tests		Observations
5	Add 2 cm depth of FA 7 into a test-tube. Add aqueous sodium hydroxide until there is no further change. Warm the mixture.	
6	Add 2 cm depth of FA 7 into a test-tube. Add aqueous barium nitrate until there is no further change. Add dilute nitric acid until there is no further change.	
7	Add 2 cm depth of FA 7 to a test-tube. Add a 1 cm depth of aqueous silver nitrate. Add aqueous ammonia to the mixture, with shaking, until the aqueous ammonia is in excess. Filter if necessary and use the resulting filtrate for Test 8 .	
8	Add 1 cm ³ of the resulting filtrate from Test 7 into a clean and dry boiling tube. Add 1 drop of sodium hydroxide and 10 drops of FA 8 . Shake well and warm the mixture in a beaker of hot water for five minutes.	

[3]

☐ M32
☐ M33
☐ M34
☐ M35

☐ M36
☐ M37
☐ M38

- 3 (b) (i) Identify the ions present in **FA 6** and **FA 7**.

Cations in **FA 6**: and

Anion in **FA 6**:

Cation in **FA 7**:

Anion in **FA 7**:

☐

M39

☐

M40

☐

M41

[3]

- (ii) Explain, with the aid of a suitable equation, the observations when dilute nitric acid was added to the resulting filtrate in **Test 1**.

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☐

M42

.....

☐

M43

.....

[2]

.....

- (c) (i) Based on your observations in **Test 8**, identify the functional group present in **FA 8**.

☐

M44

Functional group present in **FA 8**:

[1]

- (ii) Briefly explain the role of the resulting filtrate from **Test 7** in **Test 8**.

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☐

M45

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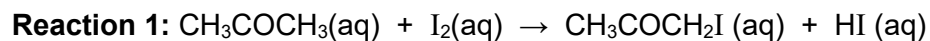
[1]

[Total: 14]

4 Planning

You are to plan a series of experiments to verify that the order with respect to iodine in the iodination of propanone is zero.

The iodination of propanone is catalysed by acid, to form iodopropanone, as shown in the equation below.



You may assume that you are provided with:

- propanone, CH_3COCH_3
- dilute sulfuric acid, H_2SO_4
- aqueous solution of iodine, I_2
- sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$
- sodium hydrogencarbonate, NaHCO_3
- starch indicator
- stopwatch
- the equipment normally found in a school or college laboratory

The order with respect to $[\text{I}_2]$ may be confirmed by preparing a reaction mixture containing H_2SO_4 , I_2 and a large excess of CH_3COCH_3 .

Portions of the reaction mixture are

- removed at timed interval,
- quenched by adding to an excess of NaHCO_3 ,
- titrated against a standard solution of $\text{S}_2\text{O}_3^{2-}$.

- You should plan to make a reaction mixture containing

- This reaction mixture contains a large excess of propanone.

- apparatus you would use,
- the procedure you would follow,
- the measurements you would make.

In your plan it is **not** necessary to refer to concentrations or to perform calculations.

[illegible]

- ☐ M46
- ☐ M47
- ☐ M48
- ☐ M49
- ☐ M50
- ☐ M51

- 4 (b) Sketch on Fig. 4.1 the graph you would expect to obtain from carrying out your plan. Explain how you would verify if the order of reaction with respect to iodine is zero.

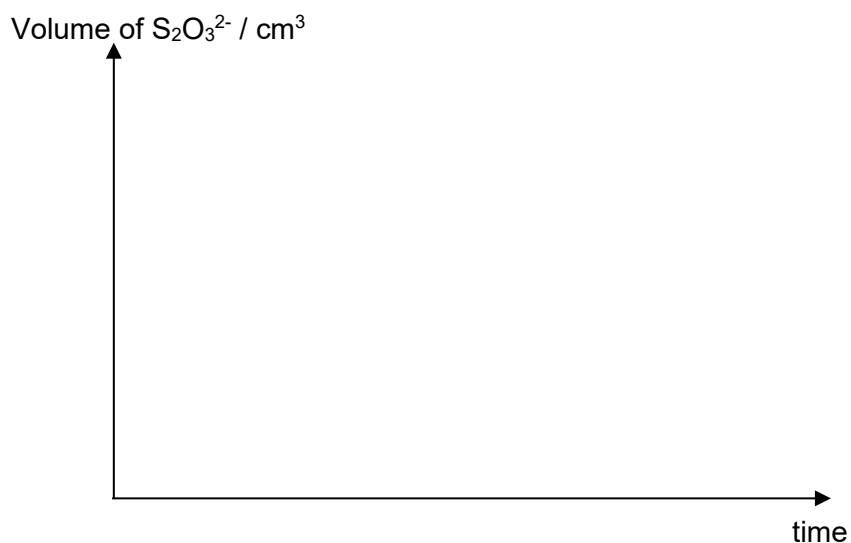


Fig. 4.1

.....
.....

[1]

☐

M52

- (c) Explain why the concentration of iodine used is very much lower than the concentration of propanone.

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.....
.....

[1]

☐

M53

- 4 (d) Suggest **two** reasons why aqueous NaHCO_3 is preferred over aqueous NaOH as the reagent for quenching the reaction mixture.

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☐

M54

☐

M55

[2]**[Total: 10]**

Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	ammonia produced on heating	–
barium, Ba ²⁺ (aq)	no ppt. (if 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 giving dark green solution	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

(b) Reactions of anions

<i>anion</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 pale 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; NO liberated by dilute acids (colourless $\text{NO} \rightarrow$ (pale) brown NO_2 in air)
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	SO_2 liberated on warming with dilute acids; gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in dilute strong acids)

(c) 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
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

(d) Colour of halogens

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple