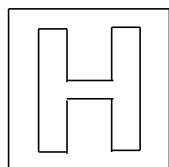


CANDIDATE
NAME

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CLASS

26S0



RAFFLES INSTITUTION
2026 YEAR 6 PRELIMINARY EXAMINATION

Higher 2



CHEMISTRY

9476/04

Paper 4 Practical

26 August 2026

2 hours 30 minutes

Do NOT turn over the Question Booklet until you are told to do so.

READ THESE INSTRUCTIONS FIRST.

Write your name and class on the space provided when instructed to do so.

Give details of the practical shift and laboratory where appropriate, in the space provided.

Write in dark blue or black pen.

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

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

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

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

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.

Qualitative Analysis Notes are printed on pages 22, 23 and 24.

Shift	
Laboratory	
Bench Number	

For Examiner's Use	
Question	Marks
1	/ 18
2	/ 10
3	/ 12
4	/ 10
Total	/ 50

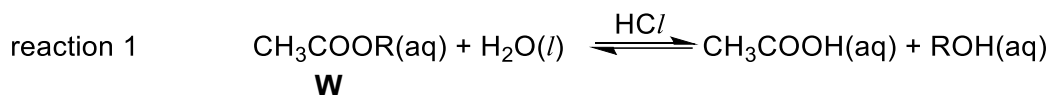
This document has **24** pages. Any blank pages are indicated.

Answer **all** questions in the space provided.

1 Determination of the equilibrium constant for the hydrolysis of an ester

Compound **W** is an ester with the formula CH_3COOR .

W undergoes hydrolysis catalysed by acid as shown in reaction 1 below.



You are to perform an experiment to determine the equilibrium constant, K_1 , for the hydrolysis of **W**.

An aqueous solution of **W** was mixed with dilute HCl . Immediately after mixing, the concentration of **W** was $0.0600 \text{ mol dm}^{-3}$ and the concentration of HCl was $0.0300 \text{ mol dm}^{-3}$. The mixture was left in the laboratory for 1 week to allow it to reach equilibrium. The resultant mixture is labelled **FA 1**.

The total amount of CH_3COOH and HCl in **FA 1** can be determined by titrating against a standard solution of sodium hydroxide.

FA 2 is $0.100 \text{ mol dm}^{-3}$ sodium hydroxide solution.

Solution T is thymolphthalein indicator.

(a) (i) Titration of FA 1 against FA 2

1. Fill a burette with **FA 2**.
2. Pipette 25.0 cm^3 of **FA 1** into a 250 cm^3 conical flask.
3. Add about 6 drops of **Solution T** to the conical flask.
4. Titrate the **FA 1** in the conical flask with **FA 2** until the solution in the conical flask changes from colourless to a permanent pale blue colour.
5. Record your titration results, to an appropriate level of precision, in the space provided on page 3.
6. Perform sufficient titrations until consistent results are obtained.

Results

[5]

- (ii) From your titration results, obtain a suitable volume of **FA 2** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 2** = [1]

- (b) (i) Calculate the amount of sodium hydroxide present in the volume of **FA 2** in (a)(ii).

amount of NaOH = [1]

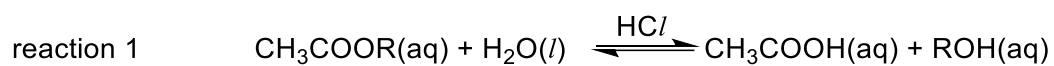
- (ii) Hence, calculate the total concentration of ethanoic acid and hydrochloric acid in **FA 1**.

total concentration of CH_3COOH and HCl = [1]

- (iii) Calculate the concentration of ethanoic acid in **FA 1**.

concentration of $\text{CH}_3\text{COOH} = \dots\dots\dots$ [1]

- (iv) Write the equilibrium constant expression, K_1 , for reaction 1.

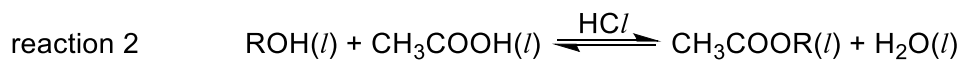


[1]

- (v) Using your answers in **(b)(iii)** and **(b)(iv)**, calculate the value of K_1 .

$K_1 = \dots\dots\dots$ [2]

- (c) Another student proposed to find K_1 by carrying out reaction 2 instead. The equilibrium constant for reaction 2 is K_2 .



The student claimed that $K_1 = \frac{1}{K_2}$ and hence, K_1 can be calculated.

Do you agree with the student? Explain your answer.

.....

[1]

- (d) The errors associated with each reading using a pipette and burette are $\pm 0.06 \text{ cm}^3$ and $\pm 0.05 \text{ cm}^3$ respectively.

Calculate the maximum total percentage error of the concentration of ethanoic acid in **FA 1**. You should assume an average titre result of 20.00 cm^3 .

maximum total percentage error =[1]

(e) **FA 3** is an aqueous solution of an alcohol **J** with molecular formula $C_5H_8O_2$.

You will perform tests to identify the functional groups in **J** and hence deduce the possible structure for **J**.

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

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

Preparation of hot water bath

Fill a 250 cm³ glass beaker with 150 cm³ of water, place it on the tripod stand and turn on the Bunsen burner. Once the water is boiling, turn off the Bunsen burner.

Use this beaker of hot water for tests **1** and **2** in Table 1.1.

(i) Carry out the tests described in Table 1.1.

Carefully record your observations in Table 1.1.

Table 1.1

tests		observations
1	Add 1 cm depth of FA 3 into a clean test-tube. To this test-tube add 10 drops of sodium hydroxide followed by iodine solution, dropwise, until a permanent yellow / orange colour is present. Warm the test-tube in the beaker of hot water for 2 minutes.	
2	Add 1 cm depth of FA 3 into a clean test-tube. Add 8 drops of Fehling's solution. Warm the test-tube in the beaker of hot water for 3 minutes.	
3	Test solution FA 3 with Universal Indicator paper.	

[3]

(ii) Alcohol **J** with molecular formula $C_5H_{10}O$ has the following features.

- It contains one chiral carbon atom.
- It decolourises aqueous bromine.
- It does not exhibit cis–trans isomerism.

Using the above information, together with your observations in Table 1.1, draw the structural formula of **J**.

[1]

[Total: 18]

2 Identification of one cation and one anion

FA 4 is a solution containing two cations and one anion. One of the cations, M^{2+} , is not found in the Qualitative Analysis Notes. An aqueous solution of M^{2+} is pink.

You will carry out tests to identify the other cation and the anion in **FA 4**.

You need not identify M^{2+} .

Test and identify any gases evolved in the tests.

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

(a) Carry out the tests in Table 2.1 on **FA 4**.

Carefully record your observations in Table 2.1.

Table 2.1

tests		observations
1	Add 1 cm depth of FA 4 into a clean test-tube. Add 1 cm depth of aqueous sodium carbonate.	
2	Add 1 cm depth of FA 4 into a clean test-tube. Add 2 cm depth of aqueous sodium hydroxide to the mixture. Filter the mixture. Add dilute nitric acid dropwise to the filtrate.	
3	Add 1 cm depth of FA 4 into a clean test-tube. Add 1 cm depth of aqueous silver nitrate. Add 2 cm depth of aqueous ammonia to the mixture. To a separate clean test-tube, add 1 cm depth dilute nitric acid. Filter the mixture into this dilute nitric acid.	

[5]

- (b) Complete Table 2.2 to identify the cation and anion in **FA 4**.

Table 2.2

cation present	
anion present	

[2]

- (c) With the aid of two suitable equations, use Le Chatelier's principle to explain your observations when the filtrate is added into dilute nitric acid in test 3.

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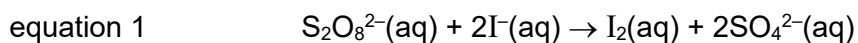
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[3]

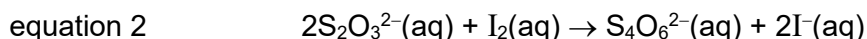
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3 Investigating the kinetics of the reaction between iodide ions and peroxydisulfate ions

When peroxydisulfate ions, $\text{S}_2\text{O}_8^{2-}(\text{aq})$, reacts with aqueous iodide ions, $\text{I}^-(\text{aq})$, a brown solution, $\text{I}_2(\text{aq})$, is formed.



If a small amount of thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, is present in the reaction mixture, the iodine, $\text{I}_2(\text{aq})$, produced will react immediately with thiosulfate ions, $\text{S}_2\text{O}_3^{2-}(\text{aq})$, as shown in equation 2.



When all the thiosulfate ions have been used, the iodine produced will form a blue–black complex with starch. The rate of the reaction is measured by finding the time for the blue–black colour to appear.

You are provided with the following solutions.

FA 4 is a solution known to catalyse the reaction shown in equation 1.

FA 5 is $0.200 \text{ mol dm}^{-3}$ potassium iodide, KI.

FA 6 is $0.0100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FA 7 is $0.100 \text{ mol dm}^{-3}$ ammonium peroxydisulfate, $(\text{NH}_4)_2\text{S}_2\text{O}_8$.

Solution S is starch solution.

You will perform a series of four experiments to investigate the kinetics of the reaction shown in equation 1. For each experiment, you will need to ensure that the **same total volume** of reaction mixture is used, by adding deionised water as required. For each experiment, you will measure the time, t , for the blue–black colour to appear.

- (a) Prepare a table in the space provided on page 12 in which to record, to an appropriate degree of precision:
- the volumes of **FA 7** (V_{FA7}) and deionised water (V_{water}) used
 - all values of t
 - calculated values of $\log\left(\frac{100}{t}\right)$
 - calculated values of $\log(V_{\text{FA7}})$.

Experiment 1

1. Use a 25 cm³ measuring cylinder to measure 16.0 cm³ of **FA 5** into a 100 cm³ conical flask.
2. Use a 10 cm³ measuring cylinder to measure 3.0 cm³ of **FA 6** into the same conical flask.
3. Use a second 25 cm³ measuring cylinder to measure 14.0 cm³ of deionised water into the same conical flask.
4. Add 5 drops of **Solution S** into the conical flask.
5. Use a third 25 cm³ measuring cylinder to measure 8.0 cm³ of **FA 7**.
6. Pour the **FA 7** into the conical flask, starting the stopwatch during this addition.
7. Mix the contents thoroughly by swirling the conical flask several times. Then place the flask on a white tile.
8. Stop the stopwatch at the first appearance of the blue-black colour.
9. Record the time taken, to the nearest second, in your table.
10. Discard the reaction mixture.
11. Wash out the flask thoroughly with tap water. Stand the flask upside down on a paper towel to drain.

Experiments 2 to 4

Repeat experiment 1 three times, adding 10.0 cm³, 12.0 cm³ and 16.0 cm³ of **FA 7** respectively in step 5.

In each experiment, you should adjust the volume of deionised water in step 3 to ensure the **same total volume** of reaction mixture is used.

You should alternate the use of the two 100 cm³ conical flasks.

Record volumes of **FA 7** and water, the time taken and the calculated values of $\log\left(\frac{100}{t}\right)$ and $\log(V_{\text{FA7}})$ in your table.

Results

[4]

- (b) (i) Plot a graph of $\log\left(\frac{100}{t}\right)$ on the y-axis and $\log(V_{FA7})$ on the x-axis on the grid in Figure. 3.1. Draw the best-fit straight line.

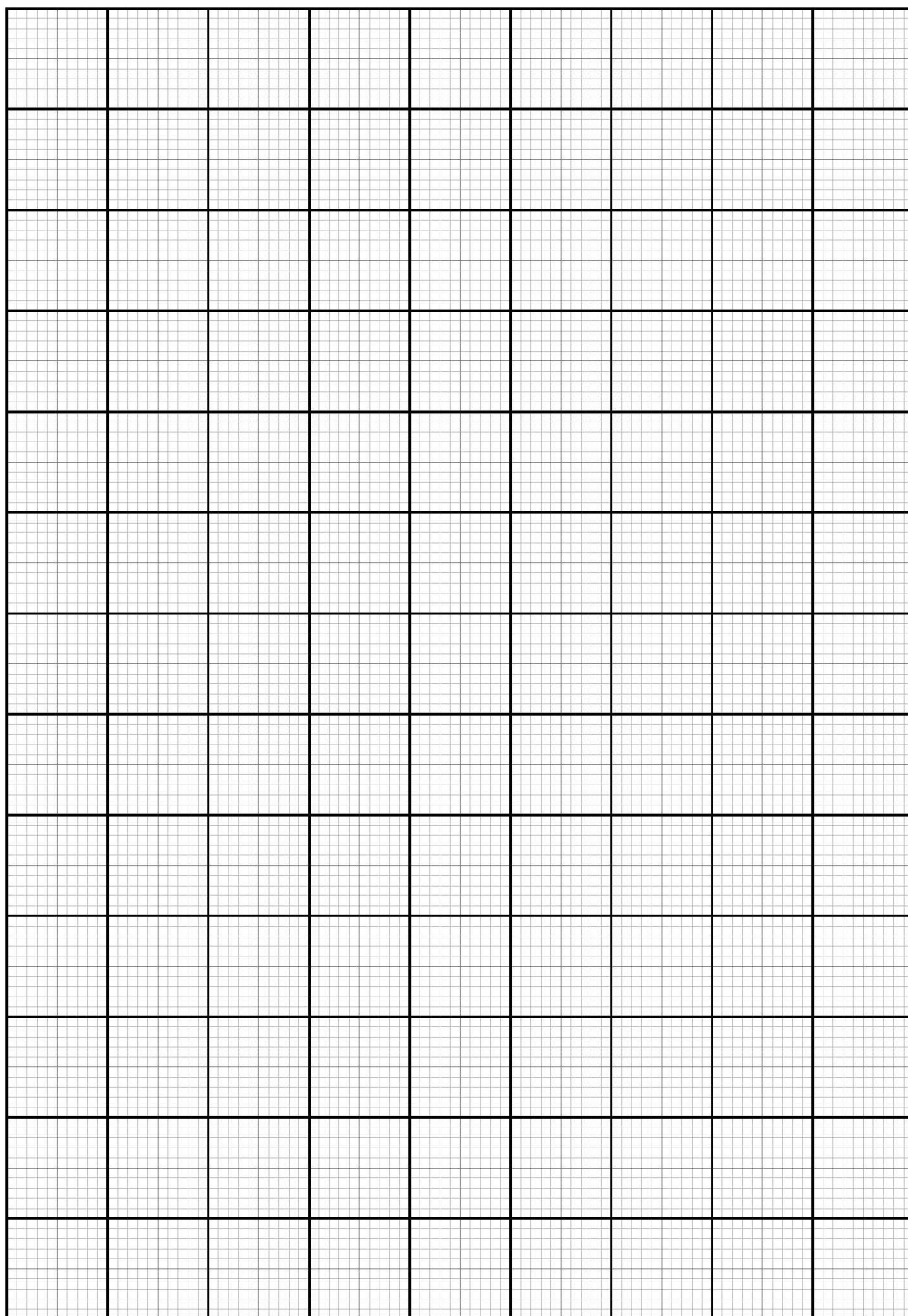


Figure. 3.1

[3]

- (ii) The gradient of the best-fit straight line gives the order of reaction with respect to peroxydisulfate ions.

Calculate the gradient of the line to three significant figures, showing your working clearly. Hence, deduce the order of the reaction with respect to peroxydisulfate ions.

gradient = [1]

order of reaction with respect to $S_2O_8^{2-}$ = [1]

FA 4 contains a cation, M^{2+} , which is known to catalyse the reaction shown in equation 1. The common oxidation states of M are +2 and +3.

- (c) Modify the steps from experiment 1 and conduct an additional experiment, experiment 5, to show that **FA 4** catalyses the reaction shown in equation 1.

Use 8.0 cm^3 of **FA 4** for experiment 5.

Record the volumes of **FA 7** and water, and the time taken, in Table 3.1.

Table 3.1

$V_{\text{FA4}} / \text{cm}^3$	$V_{\text{water}} / \text{cm}^3$	$V_{\text{FA7}} / \text{cm}^3$	t / s
8.0			

[1]

- (d) With the aid of two equations, explain how M^{2+} in **FA 4** catalyses the reaction shown in equation 1.

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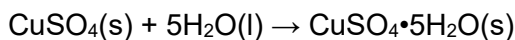
..... [2]

[Total: 12]

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4 Planning – Determination of the enthalpy change for the hydration of anhydrous copper(II) sulfate

Anhydrous copper(II) sulfate undergoes hydration as shown.



Instead of a direct measurement, the enthalpy change for this reaction, $\Delta H_{\text{hydration}}$, is determined indirectly using Hess's Law by measuring the enthalpy of solution for both anhydrous and hydrated copper(II) sulfate in water.

In this question, you are to plan an experiment that would provide sufficient data to allow you to determine an accurate and reliable value for the enthalpy change of solution of anhydrous copper(II) sulfate, $\Delta H_{\text{solution}}$.

- (a) A preliminary investigation indicated that $\Delta H_{\text{solution}}$ of anhydrous copper(II) sulfate is approximately $-65.0 \text{ kJ mol}^{-1}$.

Calculate the **minimum** mass of anhydrous copper(II) sulfate required to ensure a temperature rise of at least 5°C .

You should assume that 100 cm^3 of water is used.

You should also assume that the specific heat capacity of the solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ and the density of the solution is 1.00 g cm^{-3} .

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

minimum mass of anhydrous $\text{CuSO}_4 = \dots\dots\dots$ [1]

- (b) Plan a procedure to determine the maximum temperature change, ΔT_{max} , graphically for the reaction between anhydrous copper(II) sulfate and water, when anhydrous copper(II) sulfate is added to water.

Measurements should be taken:

- before the reaction starts,
- during the reaction,
- for some time after the reaction is complete.

You may assume that you are provided with:

- 12 g of anhydrous copper(II) sulfate,
- the equipment normally found in a school or college laboratory.

Your plan should include brief details of:

- the apparatus you would use,
- the quantities you would use, so that there is an appropriate temperature change,
- the measurements you would make to allow a suitable temperature–time graph to be drawn,
- how you would ensure that an **accurate** and **reliable** value of $\Delta H_{\text{solution}}$ is obtained.

[5]

- (c) Sketch, on Figure 4.1, the graph you would expect to obtain using the measurements you planned to make in (b). Show on your graph how the maximum temperature change, ΔT_{max} , can be determined.

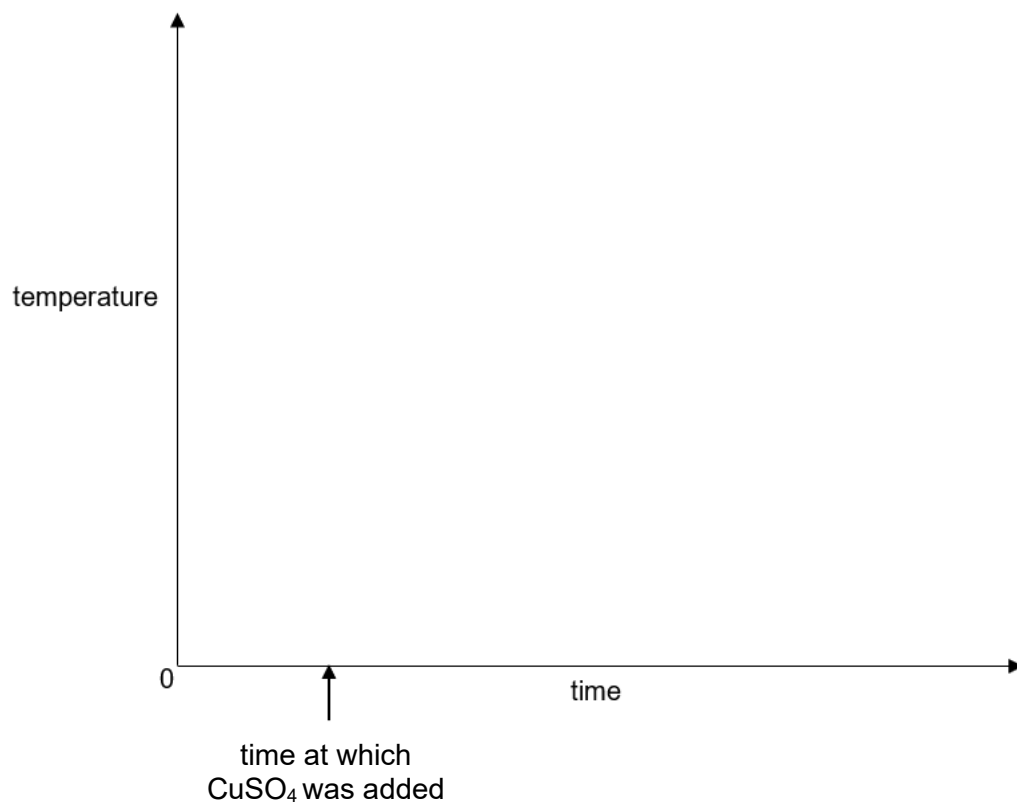


Figure 4.1

[2]

- (d) The molar enthalpy change of solution, $\Delta H_{\text{solution}}$, for hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$, is $+12.0 \text{ kJ mol}^{-1}$.

Calculate a value for $\Delta H_{\text{hydration}}$ of anhydrous copper(II) sulfate, $\text{CuSO}_4(\text{s})$.

You should assume that $\Delta H_{\text{solution}}$ of anhydrous copper(II) sulfate is $-65.0 \text{ kJ mol}^{-1}$.

[2]

[Total: 10]

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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

(e) Tests for organic compounds

<i>organic compounds</i>	<i>reactions</i>
alkene	decolourises orange Br ₂ (aq)
chloroalkane	heat with NaOH(aq), white ppt. formed on adding dilute HNO ₃ , followed by Ag ⁺ (aq)
bromoalkane	heat with NaOH(aq), pale cream ppt. formed on adding dilute HNO ₃ , followed by Ag ⁺ (aq)
iodoalkane	heat with NaOH(aq), yellow ppt. formed on adding dilute HNO ₃ , followed by Ag ⁺ (aq)
alcohol	• forms white fumes with solid PCl₅ • decolourises purple acidified KMnO₄(aq) on heating (for primary and secondary alcohols) • gives pale yellow ppt. with alkaline I₂(aq) on warming (for alcohols with CH₃CH(OH)– group)
phenol	decolourises orange Br ₂ (aq) and forms a white ppt
carbonyl compounds (aldehydes and ketones)	• gives orange ppt. with 2,4-dinitrophenylhydrazine • gives pale yellow ppt. with alkaline I₂(aq) on warming (for carbonyl compounds with CH₃CO– group) • gives red-brown ppt. with Fehling's solution on warming (for aliphatic aldehydes) • gives silver mirror with Tollens' reagent on warming (for aldehydes)
carboxylic acid	• CO₂ liberated with Na₂CO₃(aq) • gives white fumes with solid PCl₅
phenylamine	decolourises orange Br ₂ (aq) and form a white ppt
primary amide	NH ₃ liberated on heating with NaOH(aq)