ANDERSON SERANGOON JUNIOR COLLEGE

2024 JC 2 PRELIMINARY EXAMINATION

NAME:__________________________ (   ) **CLASS:** 24 /____

CHEMISTRY **9729/04**

Paper 4 Practical

21 August 2024

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Give details of the practical shift and laboratory where appropriate, in the boxes 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 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.
Quantitative Analysis Notes are printed on pages 23 and 24.

Shift
Laboratory

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 16**
2	**/ 14**
3	**/ 16**
4	**/ 9**
Total	**/ 55**

This document consists of **20** printed pages.

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

1 Investigation of the kinetics of the catalysed decomposition of hydrogen peroxide

Hydrogen peroxide decomposes very slowly to form water and oxygen gas as shown in equation **1**.

equation **1** $2H_2O_2 \longrightarrow 2H_2O + O_2$

Many transition element ions are able to catalyse the decomposition of hydrogen peroxide. Iron(III) nitrate, $Fe(NO_3)_3$, is an effective catalyst for this reaction.

FA 1 is 0.170 mol dm^{-3} aqueous hydrogen peroxide, H_2O_2
FA 2 is 0.2 mol dm^{-3} sulfuric acid, H_2SO_4
FA 3 is 0.020 mol dm^{-3} potassium manganate(VII), $KMnO_4$

You are also provided with **iron(III) nitrate**, $Fe(NO_3)_3$

You will add a measured volume of **iron(III) nitrate** to a measured volume of **FA 1** and, at timed intervals, transfer aliquots (portions) of the reaction mixture to titrate remaining H_2O_2 against $KMnO_4$ in **FA 3**.

Acidified $KMnO_4$ and H_2O_2 react as shown in equation **2**.

equation **2** $2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$

(a) (i) Preparation and titration of the reaction mixture

Notes:

You will perform each titration **once** only. Great care must be taken that you do not overshoot the end-point.

Once you have started the stopwatch, it must continue running for the duration of the experiment. You must **not** stop it until you have finished this experiment.

You should aim to transfer your first aliquot **within the first three minutes** of starting the reaction.

You should aim **not** to exceed a maximum reaction time of 25 minutes for this experiment.

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

- the time of transfer, *t*, in minutes and seconds,
- the decimal time, t_d, in minutes, to 0.1 min, for example, if t = 4 min 33 s then t_d = 4 min + 33/60 min = 4.6 min,
- the burette readings and the volume of **FA 3** added.

1. Fill a burette with **FA 3**.

2. Using a measuring cylinder, add 100.0 cm^3 of **FA 1** to the conical flask labelled **reaction mixture**.

3. Using a measuring cylinder, add 2.0 cm^3 of **iron(III) nitrate** , in one portion, to the same conical flask. Start the stopwatch and swirl the mixture thoroughly to mix its contents.

4. Using a measuring cylinder, add 50.0 cm^3 of **FA 2** to a second conical flask.

5. Transfer a 10.0 cm^3 aliquot (portion) of the reaction mixture to a 10 cm^3 measuring cylinder, using another dropping pipette.

6. **Immediately** transfer this aliquot into the second conical flask and vigorously swirl the mixture. Read and record the time of transfer in minutes and seconds, to the nearest second, when the aliquot is added.

7. Immediately titrate the H_2O_2 in the second conical flask with **FA 3**. The end-point is reached when a permanent pale pink colour is obtained. Record your titration results.

8. Wash out the second conical flask with water.

9. Repeat steps **4** to **8** until a total of five aliquots have been titrated and their results recorded.

Results

Aliquot	1	2	3	4	5
Time of transfer, *t*	1 min 1 s	5 min 2 s	10 min 1s	15 min 2 s	20 min 2s
Decimal time, t_d / min					
Final burette reading / cm^3	29.10	24.20	19.50	16.30	34.00
Initial burette reading / cm^3	0.10	0.00	0.00	0.00	20.00
Volume of **FA3** used / cm^3					

[4]

(ii) Plot a graph of the volume of **FA 3** added, on the y-axis, against decimal time, x-axis on the grid in **Fig. 1.1**.

Draw the most appropriate best-fit curve taking into account of all your plotted points. Extrapolate (extend) this curve to t_d = 0.0 min.

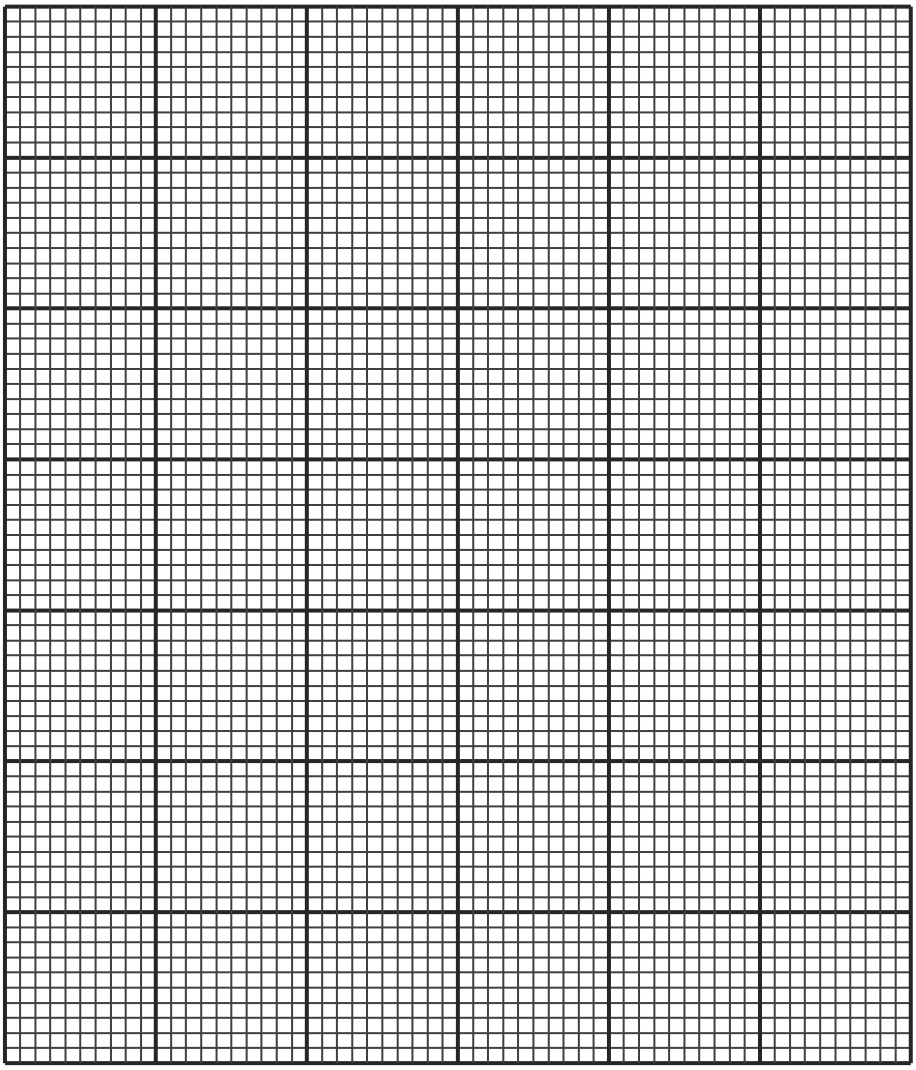

Fig. 1.1

[3]

(b) The initial rate of change of the concentration of hydrogen peroxide, **FA 1**, [H_2O_2], can be determined from the gradient of the tangent to the graph in **Fig. 1.1** at time t_d = 0.0 min.

(i) Draw a tangent to your graph in **Fig. 1.1** at time t_d = 0.0 min.

Determine the gradient of this line, showing clearly how you did this.

Gradient = ………………………… cm^3 min^{-1} [2]

(ii) Use your answer in **(b)(i)** to determine the rate of change of the amount of MnO_4^- ions required in mol min^{-1}.

rate of change of the amount of MnO_4^- ions required = ………………………….. mol min^{-1} [1]

(iii) With reference to **equation 2**, determine the amount of H_2O_2 decomposed per minute in the 10.0 cm^3 aliquot.

amount of H_2O_2 decomposed per minute = ………………………….. mol min^{-1} [1]

(iv) Hence, deduce the rate of change of $[H_2O_2]$ at t_d = 0.0 min, in mol dm^{-3} min^{-1}.

rate of change of $[H_2O_2]$ at t_d = 0.0 min = …………………… mol dm^{-3} min^{-1} [1]

(v) The procedure that you followed in **1(a)(i)** can be modified to determine the order of reaction with respect to H_2O_2.

Outline how you would verify if decomposition of hydrogen peroxide is first order with respect to H_2O_2 using the **initial rates method**. Your plan should include:

- the further experiments to conduct and data to collect,
- suggestion of a suitable graph to explain of how the data obtained can be used to determine order of reaction from initial rates**.**

No details regarding the use of specific glassware are required.

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(vi) By considering suitable half-equations in the table below, write **two** equations to show how Fe^{3+}(aq) acts as a homogeneous catalyst in the decomposition of hydrogen peroxide.

Electrode reaction
$Fe^{3+} + 3e \rightleftharpoons Fe$
$Fe^{3+} + e \rightleftharpoons Fe^{2+}$
$H_2O_2 + 2H^+ + 2e \rightleftharpoons 2H_2O$
$O_2 + 2H^+ + 2e \rightleftharpoons H_2O_2$

……………………………………………………………………………………………………

…………………………………………………………………………………………………[2]

[Total: 16]

2 Determination of the relative atomic mass, A_r, of a metal X

FA 4 is a metal carbonate, $\mathbf{X}_2CO_3$.
FA 5 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

The carbonate and acid react according to the following equation.

$$\mathbf{X}_2CO_3(s) + 2HCl(aq) \rightarrow 2\mathbf{X}Cl(aq) + CO_2(g) + H_2O(l)$$

The enthalpy change, ΔH, for this reaction is −37.0 kJmol^{-1}.

You are to perform an experiment to determine the temperature rise when a known mass of the solid carbonate, $\mathbf{X}_2CO_3$, is added to an excess of hydrochloric acid. Using your results, the relative atomic mass, A_r, of the metal **X** can then be determined.

You will follow the instructions to perform the experiment twice, **run A** and **run B**.

(a)

1. Accurately weigh the weighing bottle and contents that is labelled as **FA 4**.
2. Place a clean, dry polystyrene cup inside a 250 cm^3 beaker. Using a measuring cylinder, add 50.0 cm^3 of hydrochloric acid, **FA 5**, to the polystyrene cup.
3. Stir the solution in the cup with a thermometer gently and measure the initial temperature of the **FA 5** solution, T_i.
4. Slip the thermometer through the lid of the cup.
5. Add **FA 4** to **FA 5** in the cup and secure the lid onto the cup.
6. Use the thermometer to stir the mixture gently and measure the maximum temperature of the mixture, T_{max}.
7. Reweigh the weighing bottle**.**
8. Record all measurements of mass, T_i, T_{max}, and temperature change, ΔT, for **run A** in **Table 2.1**.
9. Repeat steps 1 to 8 using a clean dry polystyrene cup and lid, fresh **FA 4** and fresh **FA 5** for **run B**.

Table 2.1

		Run A	*Run B*
Mass of weighing bottle + **FA 4**	/ g	9.028	9.111
Mass of weighing bottle + residual **FA 4**	/ g	5.554	5.677
Mass of **FA 4** added to acid	/ g		
T_i	/ °C	30.0	30.0
T_{max}	/ °C	34.5	34.3
ΔT	/ °C		

[2]

(b) For each experiment, calculate $\frac{\Delta T}{m}$, the temperature rise per gram of **FA 4** used, and hence the mean value of $\frac{\Delta T}{m}$. [where m is the mass of **FA 4** used]

$\frac{\Delta T}{m}$ for run A = …………… °C g^{-1}

$\frac{\Delta T}{m}$ for run B = …………… °C g^{-1}

The mean value of $\frac{\Delta T}{m}$ = …………… °C g^{-1} [2]

(c) Hence, calculate the amount of heat produced per gram of **FA 4** used in the reaction.

[The specific heat capacity of the final solution is 4.3 J g^{-1} K^{-1} and its density is 1.00 g cm^{-3}.]

Amount of heat produced per gram of **FA 4** used = ……………………… J g^{-1} [1]

(d) Using the answer to **(c)** and the Δ***H*** value for the reaction, determine the relative atomic mass, A_r, of the metal **X** to 1 decimal place.

[A_r: C, 12.0; O, 16.0.]

[3]

(e) Determination of the relative atomic mass, A_r, of the metal X using a graphical method.

FB 1 is prepared by dissolving 42.4 g $\mathbf{X}_2CO_3$ in an excess of 3.00 mol dm^{-3} hydrochloric acid and making the solution up to 1 dm^3 in a graduated flask by adding more 3.00 mol dm^{-3} hydrochloric acid.

A student performed a thermometric titration to determine the equivalence point for the reaction of 1.50 mol dm^{-3} sodium hydroxide, NaOH and **FB 1**.

He first measured the initial temperature, $T_{initial}$, of 50.0 cm^3 of NaOH in a dry, clean polystyrene cup supported in a 250 cm^3 beaker.

He then added 3.00 cm^3 of **FB 1** from the burette, stirred and recorded the maximum temperature reached, T_{max}. The change in temperature, ΔT ($T_{max} - T_{initial}$), was then calculated.

He repeated the process of adding **FB 1** and taking temperature readings until 48.00 cm^3 of **FB 1** has been added from the burette.

The results from his experiment are plotted in **Fig. 2.1**.

(i) Draw two lines of best fit in **Fig. 2.1** to determine the equivalence point for the titration. Each line should have a shape best suited to its plotted points. [1]

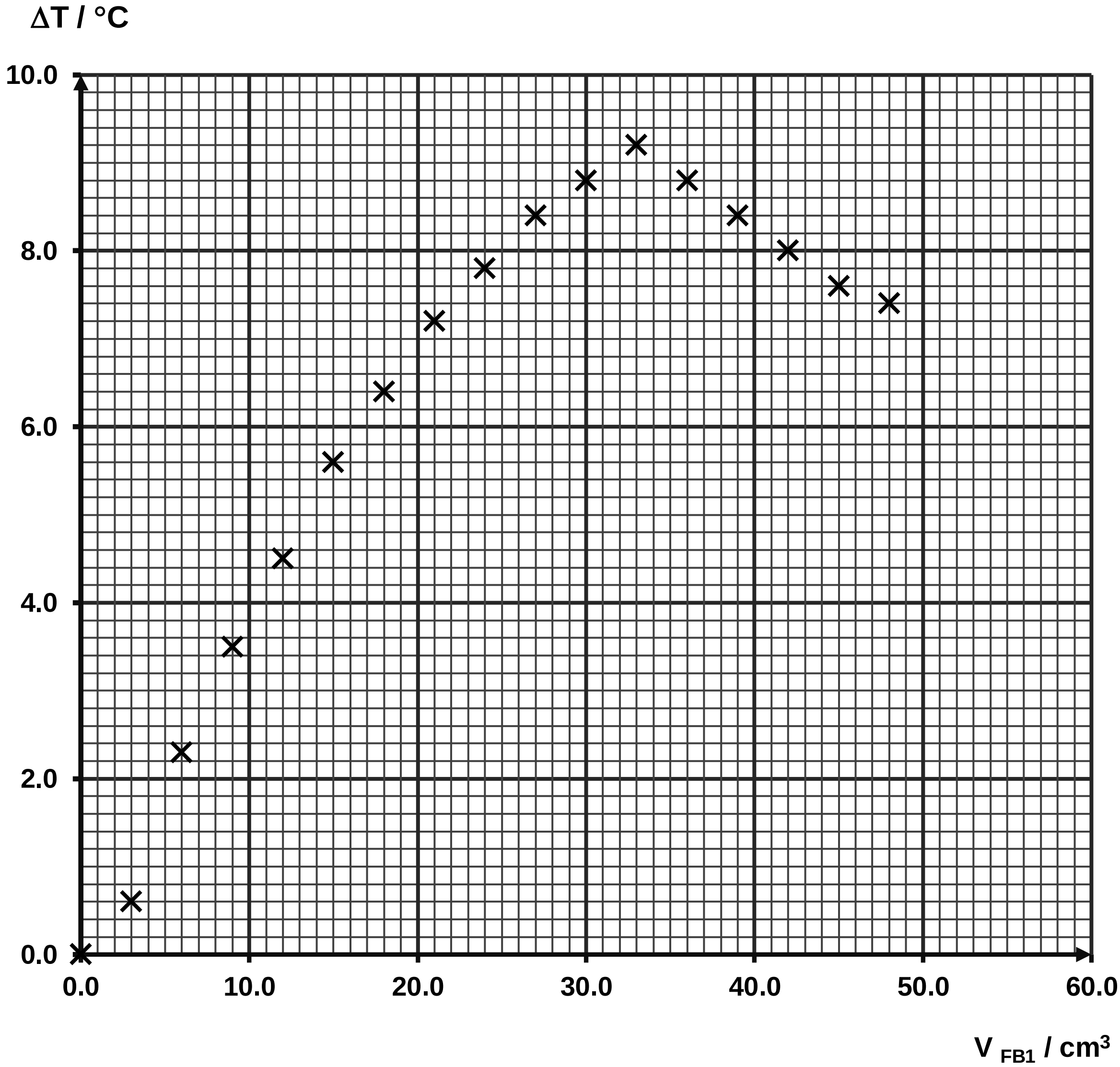

Fig. 2.1

(ii) Read from the graph the volume of hydrochloric acid, **FB 1**, added at the equivalence point of the titration.

Volume of **FB 1** = ………………….. cm^3 [1]

(iii) Use your answer to **(ii)** to calculate the concentration of the hydrochloric acid in **FB 1**.

[1]

(iv) Calculate the amount of hydrochloric acid that reacted with 42.4 g of $\mathbf{X}_2CO_3$

[1]

(v) Hence, determine the relative atomic mass, A_r, of **X** to 1 decimal place.

[A_r: C, 12.0; O, 16.0.]

A_r = …………………….. [2]

[Total: 14]

3 Qualitative Analysis

(a) **FA 6** contains **two cations** and **up to two anions**.

The possible anions that may be present are **chloride,** Cl^- and **sulfate,** SO_4^{2-}.

You will perform tests on **FA 6** to:

I. identify the two cations,
II. deduce whether **FA 6** contains one or two of the anions.

(I) Identification of cations

Carry out the following tests. Carefully record your observations in **Table 3.1**.

The reagent should be added gradually with shaking after each addition **until no further change** is observed.

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

Test and identify any gases evolved.

Table 3.1

	Test	Observations
(i)	To 1 cm depth of the solution **FA 6**, add aqueous ammonia, slowly with shaking.	Dirty-green ppt insoluble in excess ammonia Ppt turns red-brown on standing.
(ii)	Filter the mixture into a clean test tube. Keep both the residue and filtrate.	Red-brown residue Dark blue filtrate
(iii)	Wash the residue with deionised water. Discard the washings. Add dilute nitric acid to the residue. Collect the washings in a test tube. To 1 cm^3 of the washings, slowly add potassium thiocyanate (KSCN) dropwise.	Red-brown residue left Red-brown residue dissolves to give pale yellow solution. Blood/Dark red solution

[4]

(iv) From your observations in **Table 3.1**, identify the two cations present in **FA 6**.

Cation	**Evidence**

[2]

(v) Explain the observation in **(iii)** in **Table 3.1,** as fully as you can**,** with the aid of chemical equations.

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

(II) Identification of the anions in FA 6.

The possible anions that may be present in **FA 6** are **chloride,** Cl^- and **sulfate,** SO_4^{2-} only.

Use the information in Qualitative Analysis Notes on page 24 to select:

- **reagent 1**, to identify any chloride ion present,
- **reagent 2**, to identify any sulfate ion present.

Carry out tests using the two reagents.

Record your observations in the **Table 3.2**.

Table 3.2

	Reagent	Observations with FA 6	Identity of anion
1	$AgNO_3$	white ppt	
2	$Ba(NO_3)_2$	white ppt	

[2]

3 (b) **Identification of organic functional groups in FA 7.**

Half fill a 250 cm^3 beaker with hot water. This will be used as a water bath.

(i) **FA 7** is an aqueous solution of an organic compound.

Carry out the following tests on **FA 7** and record your observations in **Table 3.3**.

Test and identify any gases evolved.

Table 3.3

Test	Observations
To a 1 cm depth of **FA 7** in a test-tube add a small spatula measure of sodium carbonate.	Effervescence. Gas produced gives white precipitate with lime water. Gas is CO_2.
To a 1 cm depth of dilute sulfuric acid in a test-tube, add 2 cm depth of aqueous potassium manganate (VII). Then add 1 cm depth of **FA 7.** Leave to stand in the water bath.	Purple $KMnO_4$ decolourises
To a 1 cm depth of aqueous silver nitrate in a test-tube add a few drops of aqueous sodium hydroxide and then add aqueous ammonia slowly until the grey precipitate that forms just dissolves. This is Tollens' reagent. To this solution add a 1 cm depth of **FA 7** and leave to stand in the water bath. **Care: rinse the test tube as soon as you have completed this test.**	Silver mirror / black ppt / grey ppt

[3]

(ii) Suggest two functional groups that could be present in **FA 7**.

……………………………………….. and …………………………………………… [2]

(iii) Using **only** the elements C, H and O, as well as your answer in **(ii)**, suggest the structural formula of the organic compound in **FA 7**, containing a single carbon atom with an oxidation number of +2.

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

[Total: 16]

4 Planning

In addition to the methods described in Question 2, gravimetric analysis by weighing provides another way to determine the relative atomic mass, A_r, of **X** using a sample of $\mathbf{X}_2CO_3.10H_2O$ crystals.

The water of crystallisation in the carbonate crystals of metal **X** can be removed by heating.

The crystals do not decompose at temperatures achievable by a Bunsen flame.

(a) Using the information given, write a plan for a gravimetric analysis of $\mathbf{X}_2CO_3.10H_2O$ crystals by weighing to determine relative atomic mass of **X**.

You may assume that you are provided with:

- approximately 10 g of $\mathbf{X}_2CO_3.10H_2O$
- the equipment normally found in a school or college laboratory

Your plan should include:

- the apparatus and quantities you would use;
- an outline of the steps you would follow;
- the measurements you would make (you may find it useful to label measurements in your plan as M1, M2, etc);
- how you would ensure that your results are reliable and accurate.

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………[6]

(b) A student conducted a gravimetric analysis of $\mathbf{X}_2CO_3.10H_2O$ crystals and obtained the following results:

Mass of $\mathbf{X}_2CO_3.10H_2O$ crystals used before heating = y g
Mass of solid obtained after heating = z g

Describe how you would use the results obtained by the student to calculate relative atomic mass of **X**.

[A_r: H, 1.0; C, 12.0; O, 16.0]

[3]

[Total: 9]

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

anion	***reaction***
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and A*l* foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and A*l* foil NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-}(aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acids)

(c) Tests for gases

gas	***test and test result***
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

halogen	***colour of element***	***colour in aqueous solution***	***colour in hexane***
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