Class	Adm No

Candidate Name: ____________________

Shift
Laboratory

H

millennia institute

2021 Preliminary Examinations
Pre-University 3

H2 CHEMISTRY **9729/04**

Paper 4 Practical **1 Sept 2021**

2 hours 30 min

Candidates answer on the Question paper.

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

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

Write in dark blue or black pen.

You may use an 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.

Qualitative Analysis Notes are printed at the back of the Question Paper.

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.

Question	1	2	3	4	Total
Marks	13	20	10	12	55

This question paper consists of **19** printed pages and **1** blank page.

1 Determine the formula of the ion IO_x^- by titration

In this experiment you will determine the formula of the ion, IO_x^-.
Iodine, I_2, is formed when IO_x^- ions reacts with an excess of iodide ions.
The equation for this reaction is:

$$IO_x^- + \boldsymbol{y}\,I^- + \boldsymbol{z}\,H^+ \rightarrow \left(\frac{y+1}{2}\right) I_2 + \frac{z}{2} H_2O$$

where ***x***, ***y*** and ***z*** are all integers.
The amount of iodine produced will then be determined by titration with thiosulfate ions, $S_2O_3^{2-}$.

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

FA 1 is a solution containing 0.0150 mol dm^{-3} IO_x^- ions.
FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is 0.500 mol dm^{-3} potassium iodide, KI.
FA 4 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
starch indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Using a measuring cylinder, add 20.0 cm^3 of **FA 2** to the conical flask.
- Using a measuring cylinder, add 10.0 cm^3 of **FA 3** to the conical flask. The solution will turn brown as iodine is produced.
- Fill the burette with **FA 4**.
- Add **FA 4** from the burette until the solution in the conical flask turns yellow.
- Add 1 cm^3 of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 4** dropwise from the burette until the blue-black colour just disappears.
  This is the end-point of the titration.
- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record the burette readings and the volume of **FA 4** added in each accurate titration in the space below.

Results

M1

M2

M3

M4

M5

(b) From your titration results, obtain a value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm^3 of **FA 1** required .... cm^3 of **FA 4**. **M6**

(c) Calculations

(i) Use your answer to **(b)** to calculate the amount of iodine that was formed.

Amount of I_2 = ... **M7**

(ii) Calculate the amount of IO_x^- ions in 25.0 cm^3 of **FA 1**.

amount of IO_x^- ions=... **M8**

[Turn over

(iii) Using your answers in **(c)(i)** and **(c)(ii)**, calculate the value of ***y***.

$$IO_x^- + \boldsymbol{y}\, I^- + \boldsymbol{z}\, H^+ \rightarrow \left(\frac{y+1}{2}\right) I_2 + \frac{z}{2} H_2O$$

M9

y = ... M10

(iv) Hence, determine the value of ***x*** in IO_x^- ion.

x = ... M11

(d) **(i)** The maximum error in the volume measured using the pipette is ±0.05 cm^3.

Calculate the maximum percentage error in the volume of **FA 1** used.

Maximum percentage error:.................... M12

(ii) A student suggested that a more accurate value of ***x*** could be obtained if a burette is used to measure **FA 3** instead of a measuring cylinder.

Do you agree with the student? Explain your answer.

....

....

....

.... **M13**

[Total: 13]

[Turn over

2 Determination of the enthalpy change of the decomposition of $NaHCO_3$

You are required to determine the enthalpy change of the decomposition of $NaHCO_3$.

$$NaHCO_3 \rightarrow \tfrac{1}{2}Na_2CO_3 + \tfrac{1}{2}H_2O + \tfrac{1}{2}CO_2$$

FA 5 is anhydrous sodium hydrogencarbonate.
FA 6 is anhydrous sodium carbonate.
FA 7 is 1.0 mol dm^{-3} hydrochloric acid.

You will determine the enthalpy change of reaction for each of **FA 5** and **FA 6** with the excess addition of **FA 7**. You will then use these values to calculate the enthalpy change of the decomposition of sodium hydrogencarbonate.

(a) Determining the enthalpy change of reaction between FA 5 and FA 7

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

Method

- Weigh an empty weighing boat.
- Weigh about 4.0 g of **FA 5** in a weighing boat.
- Using a 50 cm^3 measuring cylinder, transfer 50.0 cm^3 of **FA 7** into a 250 cm^3 **beaker**.
- Stir the solution and record the initial temperature.
- Start timing and do not stop the stopwatch until the whole experiment has been carried out for 7 minutes.
- Record the temperature of the solution mixture every minute for 2 minutes.
- At exactly 3 minutes, carefully add **FA 5** into the beaker and stir the mixture. You do not need to measure the temperature of the solution at the 3rd minute. Break up any clumps while stirring.
- Record the temperature at t = 3.5 min.
- Repeat the measurement every 0.5 min until t = 7min.
- Reweigh the weighing boat containing residual sodium hydrogencarbonate.
- In an appropriate format in the space provided below, prepare tables in which to record results for your experiment in **(a)**:
  - all weighings to an appropriate level of precision,
  - all values of temperature, *T*, to an appropriate level of precision,
  - all values of time, *t*, recorded to the nearest 0.5 min.

Results

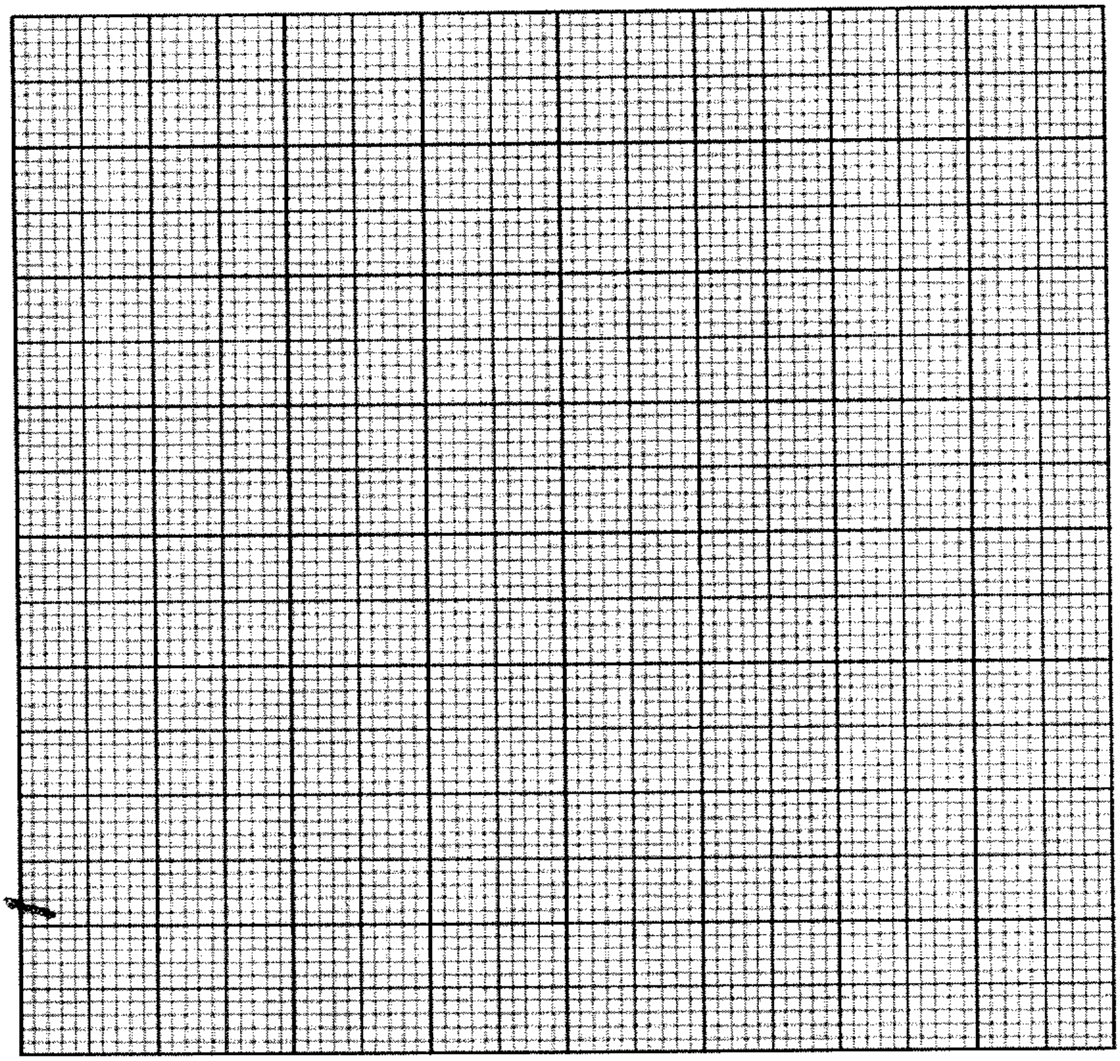
M14
M15

(b) Plot a graph of temperature, T, on the y-axis, against time, t, on the x-axis on the grid in Fig. 2.1.

Draw a best-fit straight line taking into account all of the points before t = 3.0 min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to rise steadily.

Extrapolate both lines to t = 3.0 min and determine the theoretical fall in temperature.



M16

M17

M18

Fig. 2.1

theoretical fall in temperature = ... M19

[Turn over

(c) Calculations

(i) Using the answer from **(b)**, calculate the heat energy taken in during the reaction of **FA 5** with **FA 7.**

[4.2 J is required to raise the temperature of 1 cm^3 of solution by 1 °C]

Heat energy taken in = ... **M20**

(ii) Calculate the amount of **FA 5**, $NaHCO_3$, used in the experiment.

[A_r: C, 12.0; H, 1.0; O, 16.0; Na, 23.0]

Amount of **FA 5**, $NaHCO_3$ used = ... **M21**

(iii) Hence, determine the enthalpy change of reaction, ΔH_1 for the following reaction.

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2 \text{ ---- } \Delta H_1$$

ΔH_1 = ... **M22**

(d) Determine the enthalpy change of reaction between FA 6 and FA 7

Method

- Weigh an empty weighing boat.
- Place about 2.4 g of **FA 6** in the weighing boat.
- Place a dry Styrofoam cup inside a 250 cm^3 beaker.
- Using a measuring cylinder, place 50 cm^3 of **FA 7** into the Styrofoam cup.
- Place the lid onto the cup through the thermometer from the top. Stir the liquid in the cup with the thermometer and measure its temperature. Record this temperature in your table.
- Tip cautiously the contents of the weighing boat into the acid in the Styrofoam cup, stir gently with the thermometer and record the highest temperature obtained in your table.
- Calculate the change in temperature.
- Reweigh the empty weighing boat.
- In an appropriate format in the space provided below, record all measurements of mass and temperature. Include the mass of **FA 6** used in your recording.

Results

M23
M24
M25
M26
M27

[Turn over

(e) (i) Given that 4.2 J is required to raise the temperature of 1 cm^3 of solution by 1 °C, calculate the heat energy given out in the reaction between **FA 6** and **FA 7**.

Heat energy given out = ... **M28**

(ii) Calculate the amount of **FA 6**, Na_2CO_3 added to the cup.
[A_r: C, 12.0; O, 16.0; Na, 23.0]

Amount of **FA 6**, Na_2CO_3 = ... **M29**

(f) Calculate the enthalpy change ΔH_2 for the following reaction.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2 \text{ ---- } \Delta H_2$$

M30
M31

ΔH_2 = ...

(g) Using your answers in **(c)(iii)** and **(f)**, calculate the enthalpy change of decomposition of $NaHCO_3$, ΔH_3.

$$NaHCO_3 \rightarrow \tfrac{1}{2}Na_2CO_3 + \tfrac{1}{2}H_2O + \tfrac{1}{2}CO_2 \quad \text{----} \quad \Delta H_3$$

ΔH_3 = ... **M32**

(h) A student repeats the experiment with 2.0 mol dm^{-3} HCl instead of the given concentration of 1.0 mol dm^{-3}, with the same total volume.

State and explain the effect of this change on the value of ΔH_3 that she has calculated.

....

....

....

....

....

.... **M33**

[Total: 20]

[Turn over

3 Qualitative Analysis

You are provided with three solutions, **FA 8**, **FA 9** and **FA 10**.

Perform the test-tube experiments described below and record your observations in the table.

Use fresh samples of each solution in the tests (a)(i), (a)(iii) and (a)(iv).

		observations with **FA 8**	observations with **FA 9**	observations with **FA 10**
(a)(i)	Place about 1 cm^3 of **FA 8** in a test-tube. Add sodium hydroxide, dropwise with shaking, until in excess. **Repeat using FA 9 and FA 10. Retain the mixtures for use in (a)(ii).**			
(ii)	Add hot water to a 500 cm^3 beaker provided until it is approximately half-filled. Place the test-tubes from **(a)(i)** in the beaker for 5 minutes. **While you are waiting, begin the tests below.**			
(iii)	Place about 1 cm^3 of **FA 8** in a test-tube. Add about 1 cm^3 of Fehling's solution and shake the mixture. Place the test-tube in the beaker with hot water for around 5 minutes. **While you are waiting, begin test (a)(iv).**			
(iv)	Place about 1 cm^3 of **FA 8** in a test-tube. Add two drops of acidified potassium manganate(VII) and shake the mixture. Place the test-tube in the beaker with hot water for around 5 minutes. **Repeat using FA 9 and FA 10.**			

M34

M35

M36

M37

(b) From your observations, state and quote evidence for:

- one conclusion you can draw about **FA 8**

conclusion about **FA 8** ....

evidence ....

....

- the identity of the cation in **FA 9**

cation in **FA 9** ....

evidence M38

.... M39

(c) Perform the experiment described below and record your observations in the table.

		observations
	Place about 2 cm^3 of **FA 10** in a test-tube. Add 2 pieces of magnesium ribbon. Place the test-tube in the beaker with hot water for around 5 minutes.	

M40

(d) Deduce the cation present in **FA 10**. Hence, suggest a balanced equation for one of the reactions that occurred in **(c)**.

....

.... M41

(e) **FA 10** contains an anion which is either an iodide ion or sulfate ion.
Devise and perform a simple test, based on the Qualitative Analysis Notes to identify the anion present in **FA 10**. Record your observations and hence deduce the identity of the anion in **FA 10**.

....

.... M42

.... M43

[Total: 10]

[Turn over

4 Planning

Lead can form oxides of varied formulae, including Pb_2O and PbO. Lead(II) carbonate, $PbCO_3$, decomposes on heating to form either one of these oxides.

The two possible decomposition equations are:

1. $PbCO_3(s) \rightarrow PbO(s) + CO_2(g)$

2. $2PbCO_3(s) \rightarrow Pb_2O(s) + 2CO_2(g) + \frac{1}{2}O_2(g)$

You are to plan an experiment to investigate the decomposition of lead(II) carbonate on heating and hence determine the actual decomposition product using gas collection method.

(a) You may assume that you are provided with a sample of lead(II) carbonate and the apparatus commonly found in a college laboratory.

Your plan should include:

- a sketch of the experimental set-up
- calculation of the mass of lead(II) carbonate to be used
- details of how you would carry out the experiment
- a table to show the data you would measure and record during the experiment. Include in your table any other data you would calculate from the experimental results. Insert in your table the letters **A**, **B**, **C**, etc. to represent each data.
- brief, but specific, details of how the results would then be used to reach a conclusion.

[A_r : C, 12.0; O, 16.0; Pb, 207.2]

M44

M45

[Turn over

M46

M47

M48

M49

M50

M51

(b) State one assumption made in the calculations to determine the actual decomposition product.

....

.... **M52**

(c) Suggest another method to collect the gas evolved from the reaction and state its limitation.

Method: ....

Limitation: **M53**

.... **M54**

(d) Other than the gas collection method, suggest another method to determine the decomposition product.

....

.... **M55**

[Total: 12]

END OF PAPER

BLANK PAGE

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. insoluble in excess	green ppt. 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. insoluble in excess	off-white ppt. insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

ions	*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 Al foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al 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) Test for gases

ions	*reaction*
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

Class Adm No

Candidate Name: ____________

Class	Adm No

H

millennia institute

Shift
Laboratory

2021 Preliminary Examinations
Pre-University 3

H2 CHEMISTRY **9729/04**

Paper 4 Practical **1 Sept 2021**

2 hours 30 min

Candidates answer on the Question paper.

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

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

Write in dark blue or black pen.

You may use an 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.

Qualitative Analysis Notes are printed at the back of the Question Paper.

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.

Question	1	2	3	4	Total
Marks	13	20	10	12	55

This question paper consists of **19** printed pages and **1** blank page.

1 Determine the formula of the ion IO_x^- by titration

In this experiment you will determine the formula of the ion, IO_x^-.
Iodine, I_2, is formed when IO_x^- ions reacts with an excess of iodide ions.
The equation for this reaction is:

$$IO_x^- + \boldsymbol{y}\,I^- + \boldsymbol{z}\,H^+ \rightarrow \left(\frac{y+1}{2}\right) I_2 + \frac{z}{2} H_2O$$

where ***x***, ***y*** and ***z*** are all integers.
The amount of iodine produced will then be determined by titration with thiosulfate ions, $S_2O_3^{2-}$.

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

FA 1 is a solution containing 0.0150 mol dm^{-3} IO_x^- ions.
FA 2 is dilute sulfuric acid, H_2SO_4.
FA 3 is 0.500 mol dm^{-3} potassium iodide, KI.
FA 4 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
starch indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Using a measuring cylinder, add 20.0 cm^3 of **FA 2** to the conical flask.
- Using a measuring cylinder, add 10.0 cm^3 of **FA 3** to the conical flask. The solution will turn brown as iodine is produced.
- Fill the burette with **FA 4.**
- Add **FA 4** from the burette until the solution in the conical flask turns yellow.
- Add 1 cm^3 of starch indicator to the conical flask. The solution will turn blue-black.
- Continue to add more **FA 4** dropwise from the burette until the blue-black colour just disappears.
  This is the end-point of the titration.
- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record the burette readings and the volume of **FA 4** added in each accurate titration in the space below.

Results

Initial burette reading / cm^3	0.00	0.00
Final burette reading / cm^3	22.50	22.50
Volume of **FA 4** added / cm^3	22.50	22.50
	✓	✓

M1 table w headers and units

M2 readings to 0.05 cm^3 + correct calc

M3 2 consistent values within 0.10

M4 accuracy

M5 accuracy

(b) From your titration results, obtain a value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

Volume of **FA 4** added = $\frac{22.50+22.50}{2}$

= 22.50 cm^3

25.0 cm^3 of **FA 1** required 22.50 cm^3 of **FA 4**. **M6** correct calc w working

(c) **Calculations**

(i) Use your answer to **(b)** to calculate the amount of iodine that was formed.

Amount of $S_2O_3^{2-}$ = 0.100 x $\frac{22.50}{1000}$

= 0.00225 mol

Amount of I_2 = ½ x 0.00225

= 1.13×10^{-3} mol (3sf)

Amount of I_2 = 1.13×10^{-3} mol

M7

(ii) Calculate the amount of IO_x^- ions in 25.0 cm^3 of **FA 1.**

Amount of IO_x^- = 0.0150 x $\frac{25.0}{1000}$

= 3.75×10^{-4} mol

amount of IO_x^- ions= 3.75×10^{-4} mol **M8**

[Turn over

(iii) Using your answers in **(c)(i)** and **(c)(ii)**, calculate the value of ***y***.

$$IO_x^- + \boldsymbol{y}\, I^- + \boldsymbol{z}\, H^+ \rightarrow (\tfrac{y+1}{2})\, I_2 + \tfrac{z}{2} H_2O$$

$$\frac{\text{Amount of } I_2}{\text{Amount of } IO_x^-} = \frac{\frac{y+1}{2}}{1}$$

$$\frac{1.125 \times 10^{-3}}{3.75 \times 10^{-4}} = \frac{y+1}{2}$$

y = 5 (must round off to nearest integer)

M9

M10

(c) ans to 3sf / integer + correct units

y = <u>5</u>

(iv) Hence, determine the value of ***x*** in IO_x^- ion.

$$IO_x^- + 5I^- + \boldsymbol{z}\, H^+ \rightarrow 3I_2 + \tfrac{z}{2} H_2O$$

Total charge on LHS = Total charge on RHS

$-1 - 5 + z = 0 + 0$

$z = 6$

$$IO_x^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

$\therefore x = 3$

x = <u>3</u>

M11

(d) **(i)** The maximum error in the volume measured using the pipette is ±0.05 cm^3.
Calculate the maximum percentage error in the volume of **FA 1** used.

Max % error = $\frac{0.05}{25.0}$ x 100%

= 0.200 %

Maximum percentage error: <u>0.200 %</u>

M12

(ii) A student suggested that a more accurate value of ***x*** could be obtained if a burette is used to measure **FA 3** instead of a measuring cylinder.

Do you agree with the student? Explain your answer.

Disagree. **FA 3** is added in excess, hence there is no need to use a precise instrument.

M13

[Total: 13]

[Turn over

2 Determination of the enthalpy change of the decomposition of $NaHCO_3$

You are required to determine the enthalpy change of the decomposition of $NaHCO_3$.

$$NaHCO_3 \rightarrow \tfrac{1}{2}Na_2CO_3 + \tfrac{1}{2}H_2O + \tfrac{1}{2}CO_2$$

FA 5 is anhydrous sodium hydrogencarbonate.
FA 6 is anhydrous sodium carbonate.
FA 7 is 1.0 mol dm^{-3} hydrochloric acid.

You will determine the enthalpy change of reaction for each of **FA 5** and **FA 6** with the excess addition of **FA 7**. You will then use these values to calculate the enthalpy change of the decomposition of sodium hydrogencarbonate.

(a) Determining the enthalpy change of reaction between FA 5 and FA 7

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

Method

- Weigh an empty weighing boat.
- Weigh about 4.0 g of **FA 5** in a weighing boat.
- Using a 50 cm^3 measuring cylinder, transfer 50.0 cm^3 of **FA 7** into a 250 cm^3 **beaker**.
- Stir the solution and record the initial temperature.
- Start timing and do not stop the stopwatch until the whole experiment has been carried out for 7 minutes.
- Record the temperature of the solution mixture every minute for 2 minutes.
- At exactly 3 minutes, carefully add **FA 5** into the beaker and stir the mixture. You do not need to measure the temperature of the solution at the 3rd minute. Break up any clumps while stirring.
- Record the temperature at t = 3.5 min.
- Repeat the measurement every 0.5 min until t = 7min.
- Reweigh the weighing boat containing residual sodium hydrogencarbonate.
- In an appropriate format in the space provided below, prepare tables in which to record results for your experiment in **(a)**:
  - all weighings to an appropriate level of precision,
  - all values of temperature, *T*, to an appropriate level of precision,
  - all values of time, *t*, recorded to the nearest 0.5 min.

Results

Mass of empty weighing boat / g	3.11
Mass of weighing boat with **FA 5** / g	7.11
Mass of weighing boat with residual **FA 5** / g	3.13
Mass of **FA 5** transferred / g	3.98

t / min	0.0	1.0	2.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
T / °C	30.0	30.0	30.0	27.2	25.6	25.4	25.4	25.5	25.6	25.8	25.8

M14
3 mass readings + time, temp

M15
units

(b) Plot a graph of temperature, *T*, on the *y*-axis, against time, *t*, on the *x*-axis on the grid in Fig. 2.1.

Draw a best-fit straight line taking into account all of the points before *t* = 3.0 min.

Draw another best-fit straight line taking into account all of the points after the temperature of the mixture has started to rise steadily.

Extrapolate both lines to *t* = 3.0 min and determine the theoretical fall in temperature.

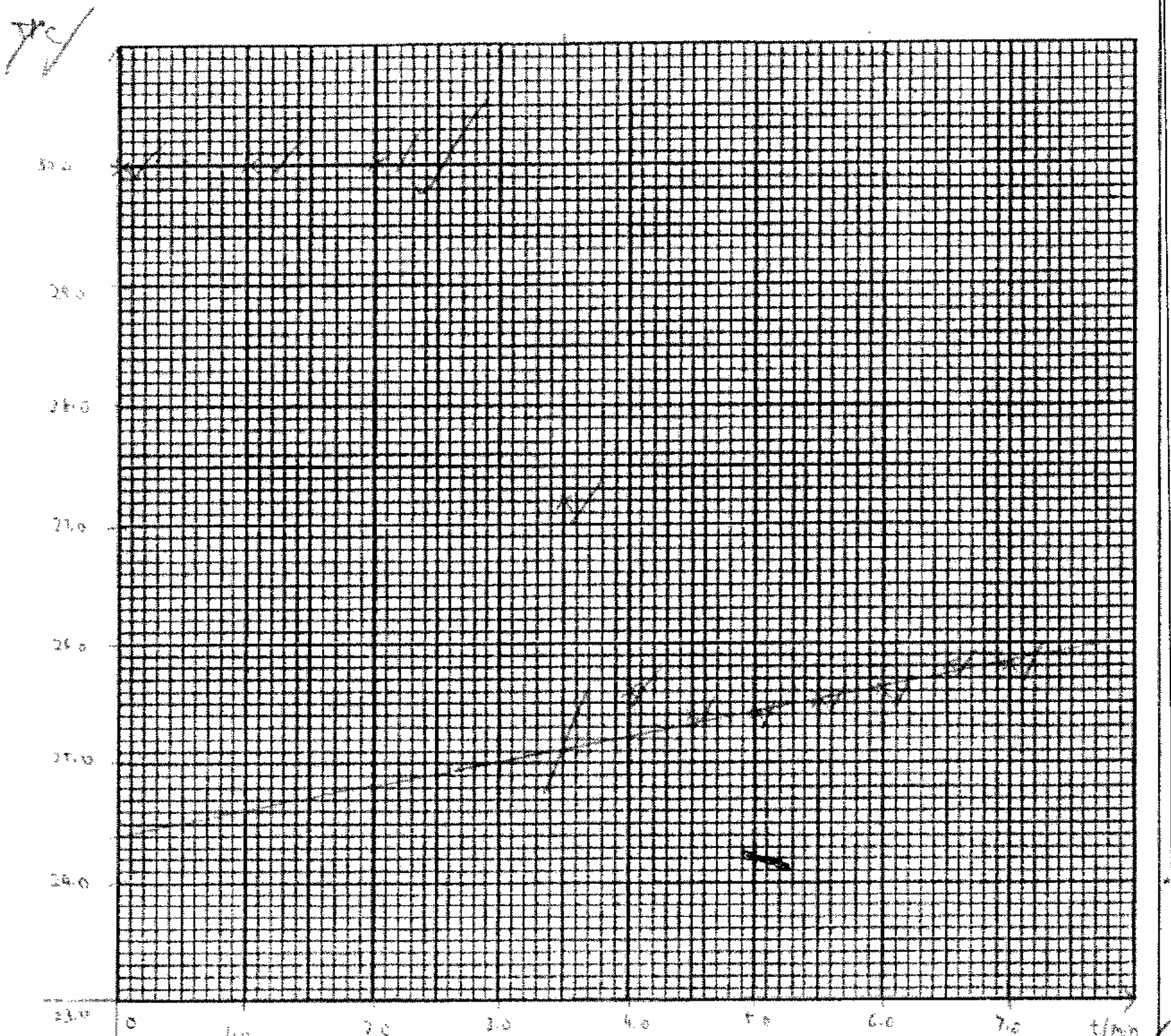


Fig. 2.1

theoretical fall in temperature = 5.0 °C

Fall in temperature = 30.0 °C − 25.0 °C → marked on graph
= 5.0 °C

M16 axes labelled with units

M17 scale

M18 all points plotted correctly

M19 2 best fit lines, extrapolated to t = 3.0, 2nd line must only use increasing / same value pts

[Turn over

(c) Calculations

(i) Using the answer from **(b)**, calculate the heat energy taken in during the reaction of **FA 5** with **FA 7.**

[4.2 J is required to raise the temperature of 1 cm^3 of solution by 1 °C]

$Q = mc\Delta T$

$= (50.0)(4.2)(5.0)$

$= 1050$ J

Heat energy taken in = 1050 J **M20**

(ii) Calculate the amount of **FA 5**, $NaHCO_3$, used in the experiment.

[A_r: C, 12.0; H, 1.0; O, 16.0; Na, 23.0]

Amount of $NaHCO_3 = \frac{3.98}{23.0+1.0+12.0+3(16.0)}$

$= 0.0474$ mol

Amount of **FA 5**, $NaHCO_3$ used = 0.0474 mol

M21

(iii) Hence, determine the enthalpy change of reaction, ΔH_1 for the following reaction.

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2 \text{ ---- } \Delta H_1$$

$\Delta H_1 = \frac{Q}{n_{LR}} \times \text{CLR}$

$= \frac{1050}{0.04738} \times 1$

$= +22.2$ kJ mol^{-1}

ΔH_1 = +22.2 kJ mol^{-1}

M22

(d) Determine the enthalpy change of reaction between FA 6 and FA 7

Method

- Weigh an empty weighing boat.
- Place about 2.4 g of **FA 6** in the weighing boat.
- Place a dry Styrofoam cup inside a 250 cm^3 beaker.
- Using a measuring cylinder, place 50 cm^3 of **FA 7** into the Styrofoam cup.
- Place the lid onto the cup through the thermometer from the top. Stir the liquid in the cup with the thermometer and measure its temperature. Record this temperature in your table.
- Tip cautiously the contents of the weighing boat into the acid in the Styrofoam cup, stir gently with the thermometer and record the highest temperature obtained in your table.
- Calculate the change in temperature.
- Reweigh the empty weighing boat.
- In an appropriate format in the space provided below, record all measurements of mass and temperature. Include the mass of **FA 6** used in your recording.

Results

Mass of empty weighing boat / g	2.85
Mass of weighing boat with **FA 6** / g	5.25
Mass of weighing boat with residual **FA 6** / g	2.87
Mass of **FA 6** transferred / g	2.38

Initial temperature / °C	30.0
Final temperature / °C	33.0
Change in temperature / °C	3.0

M23
3 mass readings + 1 mass calc + 2 temp readings + 1 temp calc

M24
2.35 ≤ mass transferred ≤ 2.45 + correct calcs

M25
all mass readings 2dp, all temp readings to 0.1 °C

M26
accuracy

M27
accuracy

(e) **(i)** Given that 4.2 J is required to raise the temperature of 1 cm^3 of solution by 1 °C, calculate the heat energy given out in the reaction between **FA 6** and **FA 7**.

$Q = mc\Delta T$
$= (50.0)(4.2)(3.0)$
$= 630$ J

Heat energy given out = 630 J **M28**

(ii) Calculate the amount of **FA 6**, Na_2CO_3 added to the cup.
[A_r: C, 12.0; O, 16.0; Na, 23.0]

Amount of $NaHCO_3 = \frac{2.38}{2(23.0)+12.0+3(16.0)}$
$= 0.0225$ mol

Amount of **FA 6**, Na_2CO_3 = 0.0225 mol **M29**

(f) Calculate the enthalpy change ΔH_2 for the following reaction.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2 \text{ ---- } \Delta H_2$$

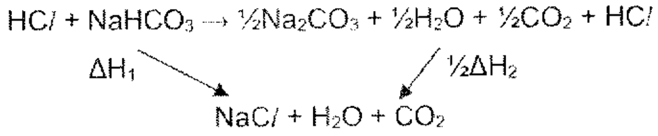
$\Delta H_1 = \frac{Q}{n_{LR}} \times CLR$
$= \frac{630}{0.0225} \times 1$
$= -28.1$ kJ mol^{-1}

M30
M31 correct signs for (c)(iii) and (f)

ΔH_2 = -28.1 kJ mol^{-1}

(g) Using your answers in **(c)(iii)** and **(f)**, calculate the enthalpy change of decomposition of $NaHCO_3$, ΔH_3.

$$NaHCO_3 \rightarrow \tfrac{1}{2}Na_2CO_3 + \tfrac{1}{2}H_2O + \tfrac{1}{2}CO_2 \text{ ---- } \Delta H_3$$



$\Delta H_3 = \Delta H_1 - \tfrac{1}{2}\Delta H_2$

$= +22.2 - \tfrac{1}{2}(-28.1)$

$= +36.2$ kJ mol^{-1}

ΔH_3 = +36.2 kJ mol^{-1}

M32

(h) A student repeats the experiment with 2.0 mol dm^{-3} HCl instead of the given concentration of 1.0 mol dm^{-3}, with the same total volume.
State and explain the effect of this change on the value of ΔH_3 that she has calculated.

No effect. This is because HCl was already used in excess, hence ΔH_1 and ΔH_2 calculated is independent of the amount of HCl. Therefore, ΔH_3 will not be affected.

M33

[Total: 20]

[Turn over

3 Qualitative Analysis

You are provided with three solutions, **FA 8**, **FA 9** and **FA 10**.

Perform the test-tube experiments described below and record your observations in the table.

Use fresh samples of each solution in the tests (a)(i), (a)(iii) and (a)(iv).

		observations with **FA 8**	observations with **FA 9**	observations with **FA 10**
(a)(i)	Place about 1 cm^3 of **FA 8** in a test-tube. Add sodium hydroxide, dropwise with shaking, until in excess. **Repeat using FA 9 and FA 10. Retain the mixtures for use in (a)(ii).**	no ppt (1)	off-white / pale brown / beige / buff ppt **and** insoluble in excess / ppt darkens (1)	green ppt and insoluble in excess / ppt darkens (1)
(ii)	Add hot water to a 500 cm^3 beaker provided until it is approximately half-filled. Place the test-tubes from **(a)(i)** in the beaker for 5 minutes. **While you are waiting, begin the tests below.**	yellow orange / brown solution (1)	brown ppt (1)	brown / black ppt (1) [ppt must be darker than previously] gas turns red litmus blue (1)
(iii)	Place about 1 cm^3 of **FA 8** in a test-tube. Add about 1 cm^3 of Fehling's solution and shake the mixture. Place the test-tube in the beaker with hot water for around 5 minutes. **While you are waiting, begin test (a)(iv).**	brick-red / red / orange ppt (1)		
(iv)	Place about 1 cm^3 of **FA 8** in a test-tube. Add two drops of acidified potassium manganate(VII) and shake the mixture. Place the test-tube in the beaker with hot water for around 5 minutes. **Repeat using FA 9 and FA 10.**	purple to colourless solution / brown ppt (1)	brown ppt (1)	purple to colourless solution (1)

M34

M35

M36

M37

(b) From your observations, state and quote evidence for:

- one conclusion you can draw about **FA 8**

conclusion about **FA 8** contains aliphatic aldehyde / is a reducing agent

evidence brick-red ppt forms when Fehling's solution was added

- the identity of the cation in **FA 9**

cation in **FA 9** Mn^{2+}

evidence off-white ppt upon addition of NaOH, which is insoluble in excess NaOH **M38**

M39

(c) Perform the experiment described below and record your observations in the table.

		observations
	Place about 2 cm^3 of **FA 10** in a test-tube. Add 2 pieces of magnesium ribbon. Place the test-tube in the beaker with hot water for around 5 minutes.	Gas evolved causes lighted splint to 'pop' **OR** Green ppt formed / Brown/black deposit on Mg / brown or black ppt

M40

(d) Deduce the cation present in **FA 10**. Hence, suggest a balanced equation for one of the reactions that occurred in **(c)**.

FA 10 contains Fe^{2+}

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ **OR** **M41**

$2Fe(OH)_2 + [O] + H_2O \rightarrow 2Fe(OH)_3$ **OR**

$Fe^{2+} + Mg \rightarrow Fe + Mg^{2+}$

(e) **FA 10** contains an anion which is either an iodide ion or sulfate ion.
Devise and perform a simple test, based on the Qualitative Analysis Notes to identify the anion present in **FA 10.** Record your observations and hence deduce the identity of the anion in **FA 10.**

To a test-tube containing 1 cm^3 **FA 10**, add 1 cm^3 of $BaCl_2$ solution. A white precipitate is formed, hence the anion is sulfate ion.

OR

To a test-tube containing 1 cm^3 **FA 10**, add 1 cm^3 of $AgNO_3$ solution, followed by excess NH_3. No yellow precipitate is formed, hence the anion is sulfate ion. **M42**

M43

[Total: 10]

[Turn over

4 Planning

Lead can form oxides of varied formulae, including Pb_2O and PbO. Lead(II) carbonate, $PbCO_3$, decomposes on heating to form either one of these oxides.

The two possible decomposition equations are:

1. $PbCO_3(s) \rightarrow PbO(s) + CO_2(g)$

2. $2PbCO_3(s) \rightarrow Pb_2O(s) + 2CO_2(g) + \frac{1}{2}O_2(g)$

You are to plan an experiment to investigate the decomposition of lead(II) carbonate on heating and hence determine the actual decomposition product using gas collection method.

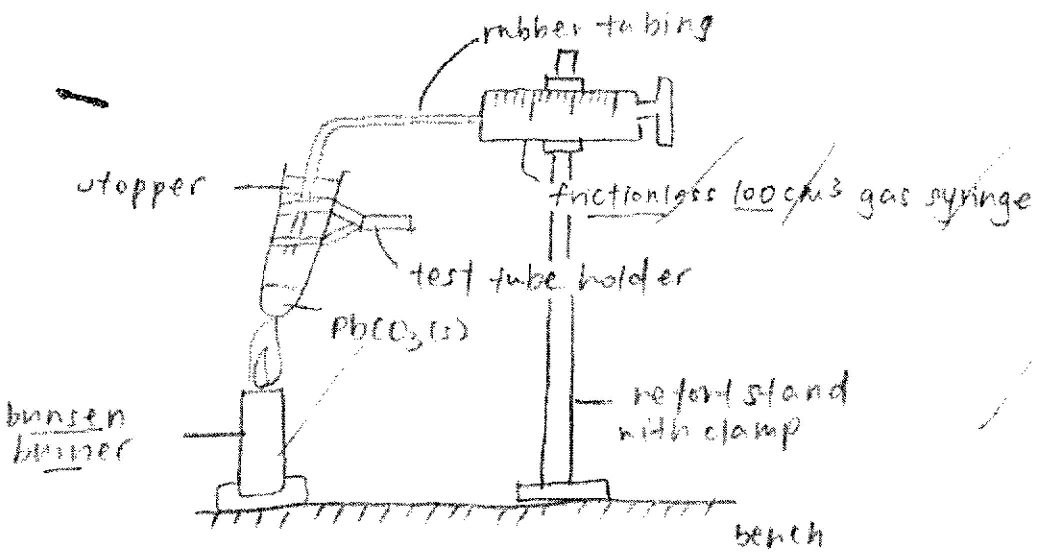
(a) You may assume that you are provided with a sample of lead(II) carbonate and the apparatus commonly found in a college laboratory.

Your plan should include:

- a sketch of the experimental set-up
- calculation of the mass of lead(II) carbonate to be used
- details of how you would carry out the experiment
- a table to show the data you would measure and record during the experiment. Include in your table any other data you would calculate from the experimental results. Insert in your table the letters **A**, **B**, **C**, etc. to represent each data.
- brief, but specific, details of how the results would then be used to reach a conclusion.

[A_r : C, 12.0; O, 16.0; Pb, 207.2]

Apparatus:



M44 Apparatus: Sketch of setup generally ok (either gas syringe or displacement of water)

M45 Apparatus: Key apparatus labelled (Bunsen burner, volume, frictionless gas syringe **OR** measuring cylinder / burette with water trough

Pre-calculations:

Since 100 cm^3 gas syringe is used, assume that 80 cm^3 of gas is collected.

Amount of gas = $\frac{80}{24000}$ = 0.00333 mol

If decomposition via equation 1,

Amount of $PbCO_3$ = Amount of gas (CO_2 only)

= 0.00333 mol

Mass of $PbCO_3$ required = 0.00333 x [207.2+12.0+3(16.0)]

= 0.891 g

If decomposition via equation 2,

Amount of $PbCO_3$ = $\frac{2}{2.5}$ x Amount of gas (CO_2 and O_2)

= 0.00267 mol

Mass of $PbCO_3$ required = 0.00267 x [207.2+12.0+3(16.0)]

= 0.713 g

To ensure that volume does not exceed 80 cm^3, use smaller mass of 0.713 g.

Procedure:

1. Using a weighing balance, weigh 0.71 g of $PbCO_3$ and transfer it into a boiling tube.
2. Set up apparatus as shown in diagram on previous page.
3. Record initial volume of the gas syringe in a table.
4. Light the Bunsen burner to begin heating. Turn off the Bunsen burner when the plunger of the gas syringe no longer moves.
5. Let the set-up cool, then record final volume of the gas syringe.

Table of measurements:

Initial volume of gas syringe / cm^3	**A**
Final volume of gas syringe / cm^3	**B**
Volume of gas evolved / cm^3	**C = B - A**

Conclusions:

Amount of $PbCO_3$ = $\frac{0.71}{207.2+12.0+3(16.0)}$ = 0.00266 mol

Amount of gas = $\frac{C}{24000}$ mol

Ratio of amount of gas to $PbCO_3$ = $\frac{C}{63.77}$

If ratio is closer to 1, product is PbO. If ratio is closer to 1.25, product is PbO_2.

M46 Pre-calc: Ensures choice of mass is linked to volume of apparatus (70-80%)

M47 Pre-calc: Determines that smaller mass of solid (from eqn 2) is more appropriate

M48 Procedure: Weighs and heats

M49 Procedure: Recording of initial volume **and** final volume only when no further change

M50 Recording: Table of volume measurements + calc with units **and** data letters

M51 Conclusion: Calc for ratio of amount of gas to amount of $PbCO_3$ used

[Turn over

(b) State one assumption made in the calculations to determine the actual decomposition product.

Gas syringe: The volume of gas collected is at room temperature and pressure

Water displacement: No gas dissolved in the water **M52**

(c) Suggest another method to collect the gas evolved from the reaction and state its limitation.

Water displacement: CO_2 is slightly soluble in water (1), hence some gas may have been lost (1) which makes the data collected unreliable. **M53**

OR **M54**

Gas syringe: There is some friction in the gas syringe (1), which results in the plunger not moving properly, (1) hence making the data collected unreliable.

(d) Other than the gas collection method, suggest another method to determine the decomposition product.

Gravimetry / test the gas with a glowing splint.

M55

[Total: 12]

END OF PAPER

BLANK PAGE

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. insoluble in excess	green ppt. 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. insoluble in excess	off-white ppt. insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

ions	*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 Al foil
nitrite, $NO_2^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil; NO liberated by dilute acids (colourless NO → (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) Test for gases

ions	*reaction*
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