NAME ____________________ CLASS **19S**

JURONG PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION 2020

CHEMISTRY **9729/04**

Higher 2

Paper 4 Practical

2 September 2020

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

Answer **all** questions in the spaces provided on the Question Paper.
Do not spend more than 40 minutes on Q1 and Q2.

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 18 and 19.

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.

Shift
Laboratory

For Examiner's Use	
1	/8
2	/9
3	/22
4	/16
Total	/55

This document consists of **19** printed pages.

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

For Examiner's Use

1 Inorganic Qualitative Analysis

FA 1 is a solid sample which contains two cations and one anion. One of the cations is Fe^{3+}.

Perform the tests described in Table 1.1 and record your observations in the table. Test and identify any gases evolved.

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

Table 1.1

		tests	*observations*
(a)	**(i)**	Add one spatula full of **FA 1** into a test-tube. Place about 5 cm depth of deionised water into the test-tube and shake the mixture until all the solid has dissolved. Use this **FA 1 solution** for tests **(ii)** and **(iii)**.	Lilac solid dissolves to give yellow / orange / brown solution. (✓)
	(ii)	To a 2 cm depth of **FA 1 solution** in a test-tube, add a small spatula of solid sodium carbonate.	Red-brown/brown/orange-brown ppt. (✓) Effervescence (✓) observed. CO_2 (✓) gas gives a white ppt. with limewater. (✓)
	(iii)	To a 1 cm depth of **FA 1 solution** in a boiling tube, add aqueous sodium hydroxide dropwise, with shaking, until it is in excess.	Red-brown/brown/orange-brown ppt. (✓) insoluble in excess NaOH. (✓)
		Gently warm the mixture.	Pungent NH_3 (✓) gas turns damp red litmus paper blue. (✓)
		Then filter the mixture, collecting the filtrate in a clean test-tube. Keep the filtrate for test **(iv)**.	Red-brown/brown/orange-brown residue (✓) and colourless filtrate (✓)
	(iv)	To a 1 cm depth of the filtrate from test **(iii)** in a test-tube, add $BaCl_2$(aq) dropwise. Then add dilute hydrochloric acid until no further change.	White ppt. (✓) ppt. insoluble in excess dilute hydrochloric acid. (✓)

[5]

(b) **(i)** By considering the observations made in Table 1.1 and making reference to the *Qualitative Analysis Notes*, identify the other cation and the anion present in **FA 1**.

The other cation in **FA 1** is NH_4^+

The anion in **FA 1** is SO_4^{2-}

[2]

(ii) By considering the ions present in **FA 1**, suggests an explanation for observations made in test **(a)(ii)**.

Fe^{3+}(aq) and NH_4^+(aq) undergo hydrolysis to give H^+(aq)/acidic solution which reacts with Na_2CO_3 to liberate CO_2.

Or, NH_4^+ is a conjugate acid of NH_3 and undergoes partial dissociation to give H^+(aq)/acidic solution which reacts with Na_2CO_3 to liberate CO_2.

Or, Due to high charge density of Fe^{3+}, Fe^{3+}(aq) undergoes partial hydrolysis to give H^+(aq)/acidic solution which reacts with Na_2CO_3 to liberate CO_2.

$$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$$
$$\text{Or, } NH_4^+ \rightleftharpoons NH_3 + H^+$$

$$Fe(H_2O)_6^{3+} + H_2O \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H_3O^+$$
$$\text{Or, } Fe(H_2O)_6^{3+} \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H^+$$

[1]

[Total: 8]

2 Organic Qualitative Analysis

In this question, you will deduce the structure of an organic compound, **FA 2**. The molecular formula of **FA 2** is $C_4H_8O_2$.

Perform the tests described in Table 2.1, and record your observations in the table. Test and identify any gases evolved. Some observations have been recorded.

Do not use Bunsen burner for heating. Use the hot water provided.

Table 2.1

		tests	observations
(a)	**(i)**	Place about 2 cm depth of aqueous sulfuric acid in a test-tube. To this test-tube, add 10 drops of **FA 2**, followed by 1 drop of aqueous potassium manganate(VII). Warm the mixture in the hot water bath for two minutes.	Purple $KMnO_4$ decolourised.
	(ii)	Place about 2 cm depth of aqueous silver nitrate in a test-tube. To this test-tube, add 10 drops of aqueous sodium hydroxide, followed by aqueous ammonia until a clear solution is formed. To this test-tube, add 10 drops of **FA 2**. Warm the mixture in the water bath for two minutes.	Brown ppt. dissolves in $NH_3(aq)$ to give a colourless solution. No silver mirror
	(iii)	Place about 1 cm depth of deionised water in a test-tube. To this test-tube, add 10 drops of **FA 2** and add 10 drops of aqueous sodium hydroxide. Now add iodine solution dropwise, until a permanent yellow/orange colour is obtained. Warm the mixture in the water bath for two minutes.	Pale yellow ppt. formed.
	(iv)	Place about 1 cm depth of **FA 2** in a test-tube. To this test-tube, cautiously add a small piece of sodium metal.	Effervescence observed. H_2 gas produced extinguishes a lighted splint with a "pop" sound.
	(v)	Place about 1 cm depth of **FA 2** in a test-tube. To this test-tube, add 2,4-dinitrophenylhydrazine dropwise.	Orange ppt. formed

[3]

(b) **(i)** Using the observations in **(a)(ii)** and **(v)** in Table 2.1, identify one functional group present in **FA 2**.

Give evidence(s) to support your conclusion.

Functional group: **ketone**

Evidence: It undergoes **condensation with 2,4-DNPH** to give an orange ppt. but it **does not** undergo oxidation/**react with Tollens' reagent** to give a silver mirror.

[2]

(ii) Using the observations in other tests in Table 2.1, identify the other functional group present in **FA 2**.

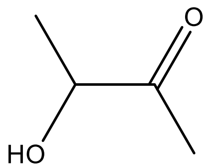
Give evidence(s) to support your conclusion.

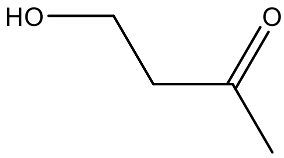
Functional group: primary or secondary **alcohol**

Evidence: It undergoes **oxidation with** acidified **$KMnO_4$** and decolourises purple $KMnO_4$. It undergoes a **redox reaction with Na** to give H_2 gas.

[2]

(iii) Suggest two possible structures of **FA 2**.





[2]

[Total: 9]

For Examiner's Use

3 Investigation of reaction between manganate(VII) ions and ethanedioate ions.

FA 3 is 0.0100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$
FA 4 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$
FA 5 is 0.200 mol dm^{-3} ethanedioic acid, $H_2C_2O_4$
FA 6 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4
FA 7 is 0.100 mol dm^{-3} potassium iodide, KI

You are also provided with a starch indicator.

Acidified potassium manganate(VII) oxidises ethanedioate ions, $C_2O_4^{2-}$ as shown in **reaction 1**. The Mn^{2+} ions produced in **reaction 1** act as a catalyst for the reaction. This is an example of 'autocatalysis'.

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$ **reaction 1**

You are to investigate how the rate of reaction changes with $[MnO_4^-]$. To do this, you will prepare a reaction mixture containing **FA 4**, **FA 5** and **FA 6**. At timed intervals, you will withdraw **five aliquots** (portions) of the reaction mixture, add them to 10 cm^3 of excess KI which will "quench" the reaction by reacting away all MnO_4^- via a redox reaction as shown in **reaction 2**.

$2MnO_4^-(aq) + 10I^-(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5I_2(aq) + 8H_2O(l)$ **reaction 2**

You will then titrate the iodine produced in the resulting solutions against sodium thiosulfate (**reaction 3**).

$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$ **reaction 3**

Your titre values will indicate the concentration of MnO_4^- remaining in the reaction mixture at different times. Hence, the rate of reaction between MnO_4^- and $C_2O_4^{2-}$ at different times can be determined by graphical analysis of your results.

You should read all of the instructions on this page and the Method on the next page before you start this experiment.

Recording your results

In an appropriate format in the space provided on **page 8**, prepare a table to record, for each of your aliquots, the

- transfer time in minutes and seconds
- titration results (*initial and final burette readings; and volume of **FA 3** added*)
- decimal time, **t**, which is the transfer time converted to minutes in one decimal place (*e.g. a transfer time of 2 min 27 s becomes 2 min + 27/60 min = 2.5 min*)

Make certain that your recorded results show the precision of your working.

(a) Method

Preparing the boiling tubes and burette

1. Using a 10 cm^3 measuring cylinder, add about 10 cm^3 of **FA 7** to each of the labelled boiling tubes, **1** to **5**.

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

Preparing the reaction mixture

3. Use appropriate measuring cylinders to add to the beaker labelled **reaction mixture**
   - 50.0 cm^3 of **FA 5**,
   - 5.0 cm^3 of **FA 6**,
   - 45.0 cm^3 of deionised water.

4. Place 25.0 cm^3 of **FA 4** into a 25 cm^3 measuring cylinder.

5. At a convenient time, pour **FA 4** into the beaker labelled **reaction mixture**. Start the stopwatch at the instant of mixing and stir the mixture thoroughly using a glass rod.

Note: *Once you have started the stopwatch, allow it to continue running for the duration of the experiment. You* ***must not stop*** *the stopwatch until you have collected all of your aliquots.*

Removing aliquots of reaction mixture

Note: *Leaving all of the titrations to be performed until after all the aliquots have been collected may cause you time problems.*

6. At approximately 1 minute, use a 10 cm^3 pipette to remove a 10.0 cm^3 aliquot of the reaction mixture. **Immediately** transfer this aliquot into the boiling tube labelled **1** and shake the mixture. Note and record the transfer time (in minutes and seconds, to the nearest second) when half of the reaction mixture has emptied from the pipette.

7. At approximately 4 minutes, repeat point **6**. Transfer this aliquot into the boiling tube labelled **2** and shake the mixture.

8. Repeat point **6** three more times at about 7 minutes, 10 minutes and 13 minutes, transferring the aliquots into the boiling tubes labelled **3** to **5**.

Titrations

Note: *You will only be able to perform each titration* ***once****. Be careful not to overshoot the end-point.*

9. Pour all the contents of boiling tube **1** into a clean conical flask. Rinse this boiling tube with deionised water and add the washings to the conical flask.

10. Record the initial burette reading. Titrate the I_2 in this solution with **FA 3** until the solution turns pale yellow. Then add about 1 cm^3 of starch indicator. The solution will turn blue-black. Continue to titrate until the blue-black colour **just** disappears at the end-point. Record the final burette reading and the volume of **FA 3** added.

11. Wash this conical flask thoroughly with water.

12. Top up the burette with **FA 3**.

13. Repeat points **9** to **11** as required for each of the remaining boiling tubes.

For Examiner's Use

(b) Experimental results

Transfer time	Final burette reading / cm^3	Initial burette reading / cm^3	Volume of **FA 3** added / cm^3	t /min
1 min 18 s	19.00	0.00	19.00	1.3
4 min 25 s	17.70	0.00	17.70	4.4
7 min 21 s	30.80	17.90	12.90	7.4
10 min 13 s	35.80	30.80	5.00	10.2
13 min 15 s	37.60	35.80	1.80	13.3

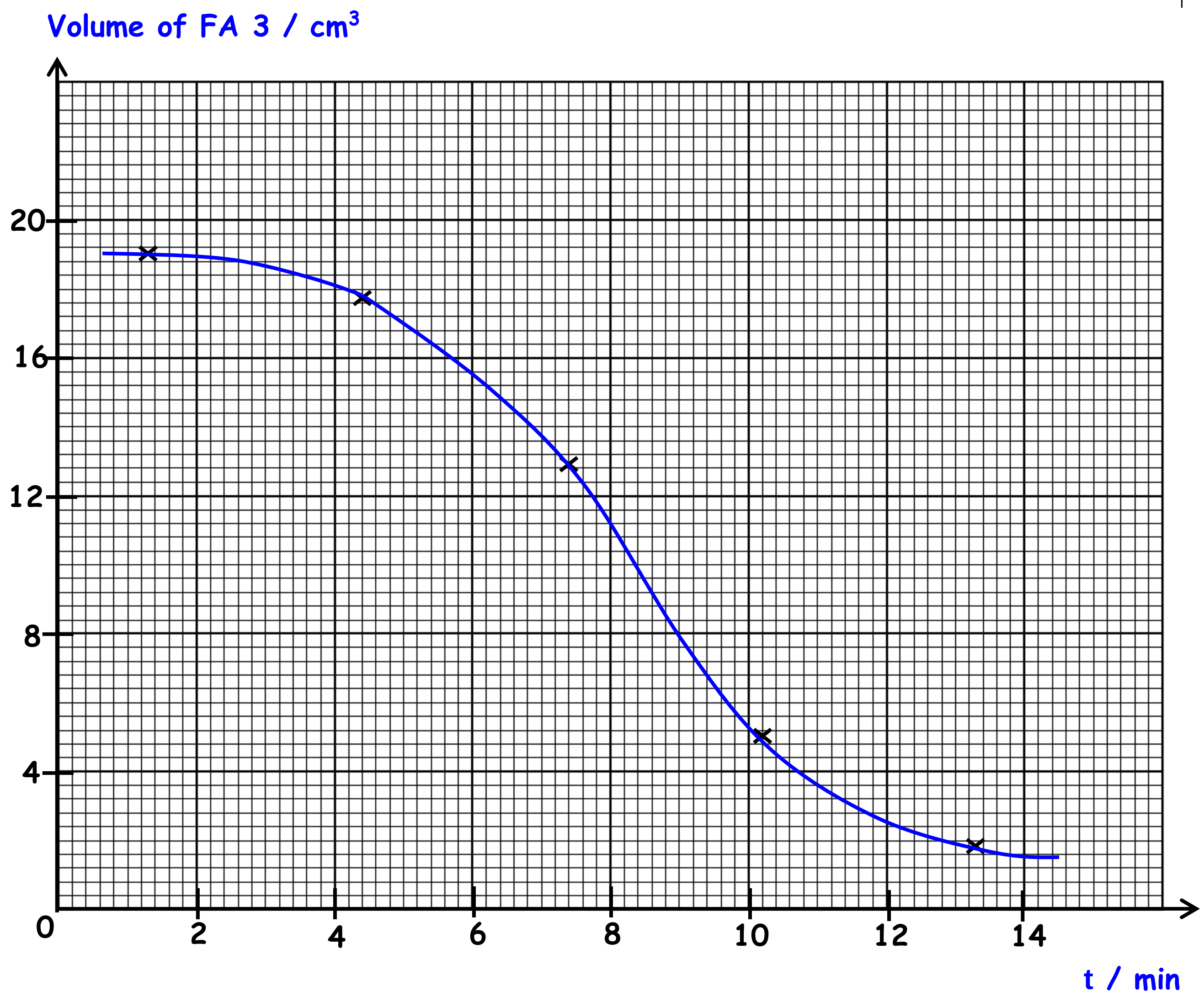
[5]

- Tabulates transfer time, initial and final burette readings, volume of FA3 added and t in a single table with correct headers and correct units. Accept 'sec' in place of 's'.
- Records all transfer times in whole no. in min and s and converts all values of t correctly to 1 decimal place in min.
- Records all initial and final burette readings + computes all titres correctly in 2 d.p.
- Enters all 5 full sets of data with all transfer times within ±59s of suggested times
- titre for first aliquot within (18.00 - 20.00) cm^3 + decreasing titre with increasing t.

(c) **(i)** On the grid below, plot a graph of the volume of sodium thiosulfate, **FA 3**, on the *y*-axis, against time, **t**, on the *x*-axis.

Draw the most appropriate line (curve) taking into account all of your plotted points.

For Examiner's Use



[3]

- Axes correct way round + axes with correct labels with units + uses proper scale with plotted points occupy at least half of the given grid in both directions.
  Do not award this mark if student uses awkward scale (e.g. 1 for 3/7).
  Accept "time" in place of 't'.
- Plots all points correctly to within $\pm \frac{1}{2}$ small square and in the correct half of a small square.
- Draws a smooth curve of best-fit based on student's data points.

(ii) Rate of reaction at time **t** is indicated by the slope of tangent at time **t**.

Describe and explain how the **shape** of the graph in **(c)(i)** shows that the reaction between MnO_4^- and $C_2O_4^{2-}$ is an autocatalysed reaction.

At the beginning/start, the slope of tangent is almost zero/small/gentle. This indicates that the **rate of reaction is low** due to **absence of Mn^{2+}/catalyst or low concentration of Mn^{2+}/cataylst**.

As the reaction proceeds, the slope of tangent increases. This indicates that the **rate of reaction increases** due to **more catalyst/Mn^{2+} is produced** or **concentration of Mn^{2+}/catalyst increases**.

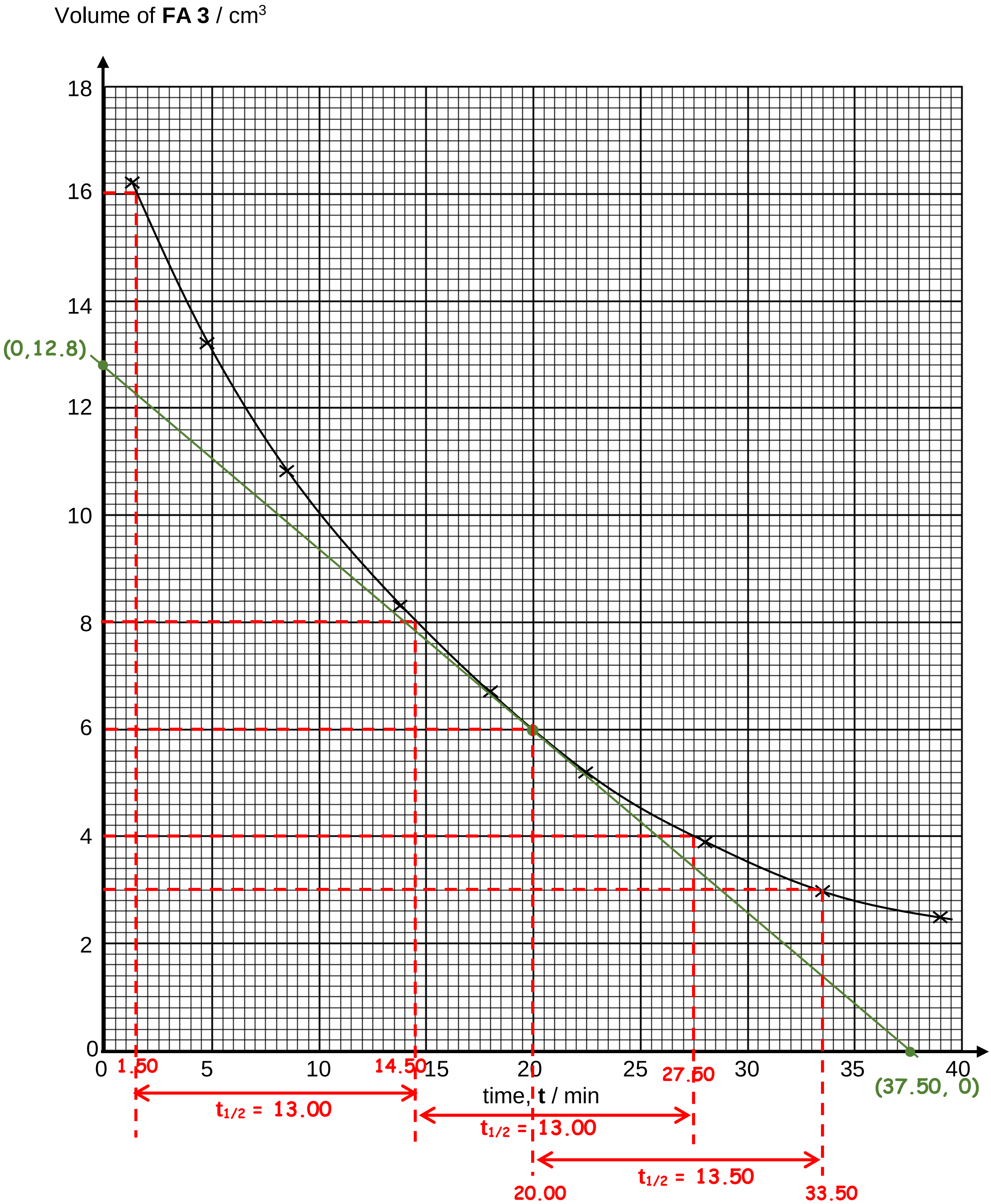
Towards the end, the slope of tangent decreases. This indicates that the rate of reaction decreases due to decrease in concentration of reactants.

[2]

For Examiner's Use

A student performed a similar experiment in cooler conditions. In point 3, she used the same volumes of **FA 5** and **FA 6** that you used but she also added 5.0 cm^3 of a solution of manganese(II) sulfate, $MnSO_4$, a source of Mn^{2+} to catalyse the reaction. She only added 40.0 cm^3 of deionised water, so the total volume used was the same as in your experiment.

(d) On the grid below, the data from the student's experiment has been plotted and the graph line has been drawn.



(d) **(i)** Use data from the graph in **(d)** to determine the order of reaction with respect to [MnO_4^-] in **reaction 1**. Draw clearly any construction lines on the graph. Explain your reasoning clearly.

Volume of $S_2O_3^{2-}$ (FA 3) required at time t is directly proportional to the [MnO_4^-] left in the reaction mixture at time t.

From the graph, **first $t_{1/2}$ = 13.00 min,**
second $t_{1/2}$ = 13.00 min,
third $t_{1/2}$ = 13.50 min.

- **shows clear construction lines on the graph to determine at least two $t_{1/2}$ (must be able to tell student's selected initial V for each $t_{1/2}$ from the working either by vertical dotted lines and/or horizontal t range line ↔)**
- **states $t_{1/2}$ values correctly (based on workings) either on the graph or in this space.**

Since **half-lives are** (approximately) **constant**, the reaction is **first order** with respect to [MnO_4^-] in reaction 1.

[4]

(ii) Draw a tangent to the graph in **(d)** at time **t** = 20 min.

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

Gradient $= \dfrac{12.8 - 0}{0 - 37.50} = -0.3413\ \text{cm}^3\ \text{min}^{-1}$

- **draws a solid gradient line touching the curve at one point, t = 20 min and it is a tangent at this point.**
- **Do not award if the line is non-tangential, does not touch the curve or crosses part of the curve.**
- **indicates chosen co-ordinates clearly on the graph + hypotenuse of "triangle" cannot be too small + correctly reads the chosen coordinates to nearest ½ small square.**
  calculates gradient correctly with a negative sign.

gradient = **-0.341 cm^3 min^{-1}** [3]

(iii) Using data from the graph in **(d)** and equations of **reaction 2** and **3**, calculate the $[MnO_4^-]$ in the reaction mixture at time **t** = 20 min.

$$2MnO_4^- + 10I^- + 16H^+ \rightarrow 2Mn^{2+} + 5I_2 + 8H_2O \qquad \textbf{reaction 2}$$
$$2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-} \qquad \textbf{reaction 3}$$

Amount of $S_2O_3^{2-}$ required to react with 10.0 cm^3 of reaction mixture at 20 min

$= \frac{6}{1000} \times 0.0100 = \underline{6.00 \times 10^{-5} \text{ mol}}$

mole ratio of MnO_4^- : I_2 : $S_2O_3^{2-}$
= 2 : 5 : 10

Amount of MnO_4^- in 10.0 cm^3 of reaction mixture at 20 min

$= \frac{1}{5} \times 6.00 \times 10^{-5} = \underline{1.20 \times 10^{-5} \text{ mol}}$

$[MnO_4^-]$ in the reaction mixture at 20 min

$= \frac{1000}{10.0} \times 1.20 \times 10^{-5} = 1.20 \times 10^{-3}$ mol dm^{-3}

$[MnO_4^-]$ at 20 min = $\underline{1.20 \times 10^{-3}}$ $\underline{\text{mol dm}^{-3}}$

- shows <u>working</u> in calculations in (d)(ii)(iii)
  AND gives <u>3 s.f.</u> in final answers in (d)(ii)(iii)
- gives <u>correct units</u> in (d)(ii)(iii)

Any calculation not attempted loses these 2 marks. [5]

[Total: 22]

For Examiner's Use

4 Planning

When sodium hydrogencarbonate, $NaHCO_3$, is heated, it decomposes to form sodium carbonate, Na_2CO_3.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g) \quad \Delta H_r$$

The enthalpy change of reaction, ΔH_r, for decomposition of $NaHCO_3$ cannot be determined directly and so an indirect method is used.

By determining the enthalpy change of reaction between Na_2CO_3(s) and hydrochloric acid, ΔH_1, and that between $NaHCO_3$(s) and hydrochloric acid, ΔH_2, you can obtain a value for ΔH_r for decomposition of $NaHCO_3$.

Experiment 1 Reaction between sodium carbonate, Na_2CO_3(s), and dilute hydrochloric acid, HC*l*(aq)

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H_1$$

You are provided with

FA 8 2.0 mol dm^{-3} hydrochloric acid, HC*l*(aq)
FA 9 a pre-weighed sample of solid sodium carbonate, Na_2CO_3(s)

You are to carry out an experiment following the method below and use the results of the experiment to determine the enthalpy change of reaction between Na_2CO_3(s) and HC*l*(aq), ΔH_1.

Read through the method. In an appropriate format in the space provided on the next page, prepare suitable tables to record your results.

Method

1. Weigh the stoppered weighing bottle labelled **FA 9** and its contents. Record the total mass of weighing bottle and **FA 9**.
2. Support the Styrofoam cup in the 250 cm^3 beaker.
3. Use a 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 8** into the Styrofoam cup. **FA 8** is in excess.
4. Place the thermometer in this **FA 8** and record the initial temperature.
5. **Carefully** add all the **FA 9**, in small portions to avoid spray, from the weighing bottle to **FA 8** in the Styrofoam cup. While adding the solid, stir the mixture constantly with the thermometer. Record the maximum temperature reached.
6. Calculate and record the maximum temperature change, ΔT, that occurred during the reaction.
7. Reweigh the stoppered weighing bottle with any residual **FA 9** and record the mass.
8. Calculate and record the mass of **FA 9** added to the cup.
9. Record your results on the next page.

For Examiner's Use

(a) (i) Experimental Results

Mass of weighing bottle with FA 9 / g	10.513
Mass of weighing bottle with residual FA 9 / g	6.308
Mass of FA 9 added / g	4.205

- Records all required mass readings in a single table with correct headers and units + all mass readings in 3 decimal places + correct computation of mass of FA 9 added.

Maximum temperature / °C	36.2
Initial temperature / °C	29.7
ΔT / °C	6.5

Accept "**Final**" in place of "**Maximum**"

- Records all required temp readings in a single table with correct headers and units + all temp readings to the nearest 0.1 °C + correct computation of ΔT (ignore any given sign).

Accuracy: δ = student's ($\Delta T/m$) – tutor's ($\Delta T/m$)
$-0.10 \le \delta \le +0.1$ °C g^{-1} $\Rightarrow$ student's $\Delta T/m$ within: 1.31–1.51 [3]

(ii) Use your results in **(a)(i)** to calculate the heat change, q, for your experiment and hence determine a value for ΔH_1.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g) \qquad \Delta H_1$$

Assume that the specific heat capacity of the final solution is 4.20 J g^{-1} K^{-1} and that its density is 1.03 g cm^{-3}. [A_r : Na, 23.0; C, 12.0; O, 16.0]

$q = m \times c \times \Delta T$
$= (50.0 \times 1.03) \times 4.20 \times 6.5$ J
$= 1406$ J
$= 1.406$ kJ

Amount of Na_2CO_3 added $= \dfrac{4.205}{106.0} = 0.049104$ mol

$\Delta H_1 = -\left(\dfrac{1.406}{0.049104}\right) = -28.6$ kJ mol^{-1}

q = 1410 J

ΔH_1 = –28.6 kJ mol^{-1} [2]

(b) Suggest what you should change to reduce the percentage error associated with the temperature readings **without** changing the apparatus.

Decrease the volume of HCl(aq) used
Or Increase the mass of the $NaHCO_3$ used

to obtain a bigger ΔT in order to reduce % error. [1]

For Examiner's Use

Experiment 2 Reaction between sodium hydrogencarbonate, $NaHCO_3$(s), and dilute hydrochloric acid, HC*l*(aq)

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g) \qquad \Delta H_2 > 0$$

The reaction between $NaHCO_3$(s) and HC*l*(aq) is an endothermic process.

The maximum temperature change occurring during this reaction may be determined graphically.

The maximum temperature change, ΔT_{max}, obtained from the graph can be used to calculate the heat change, *q*, for this experiment. Using *q*, a value for ΔH_2 may be determined.

You may assume that you are provided with

- 150 cm^3 of 2 mol dm^{-3} hydrochloric acid, HC*l*(aq)
- 10 g of solid sodium hydrogencarbonate, $NaHCO_3$(s)
- the equipment normally found in a school or college laboratory.

(c) (i) Outline how you would carry out an experiment to determine the maximum temperature change, ΔT_{max}, **graphically** for the reaction between $NaHCO_3$(s) and HC*l*(aq) in order to determine an **accurate** and **reliable** value for ΔH_2.

Your answer should include brief details of:

- the apparatus you would use,
- the quantities you would use, so that there is an excess of HC*l*(aq),
- the procedure you would follow,
- 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 $\boldsymbol{\Delta T_{max}}$ is obtained.

1. Weigh an empty weighing bottle using an electronic weighing balance which is precise to 2 or 3 decimal places.
2. Weigh accurately *6.00 g of solid $NaHCO_3$ into the weighing bottle and record the total mass.
3. Using a 50 cm^3 measuring cylinder, add *50.0 cm^3 of HC*l*(aq) into the Styrofoam/polystyrene/plastic cup supported in a big beaker.
4. Stir the HC*l*(aq) in the cup using the 0.2 °C interval thermometer and record the initial temperature of the solution.
5. At a convenient time, start the stopwatch. Record the temperature of the solution in the styrofoam cup at 30 s intervals until 2.5 min.
6. At exactly 3 min, tip the weighed $NaHCO_3$ into the styrofoam cup.
7. Stir the contents in the styrofoam cup with the thermometer and record the temperature of the solution at 3.5 min. Continue to stir the contents in the styrofoam cup and record the temperature of the solution at 30 s intervals until 10.0 min.
8. Re-weigh the weighing bottle which contains some residual $NaHCO_3$ to find out the actual mass $NaHCO_3$ added to the styrofoam cup.

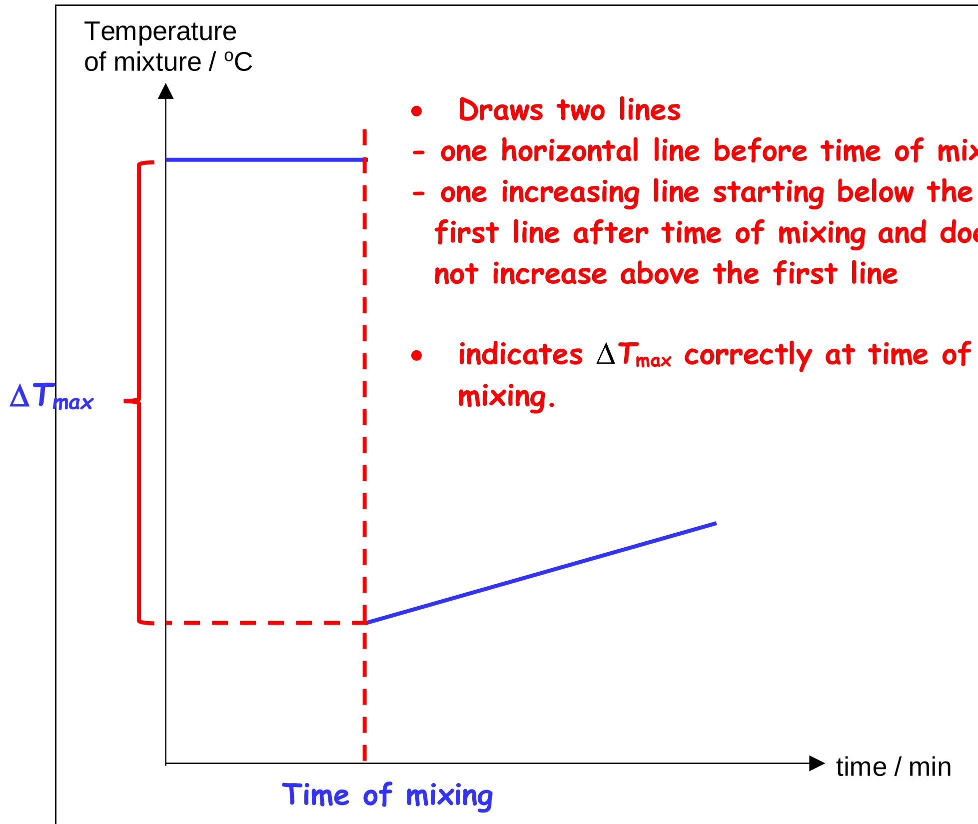
[5]

- *n($NaHCO_3$) used must be less than n(HC*l*) used.
- Measure mass of $NaHCO_3$ (limiting reagent) using a weighing balance (reject "balance/weighing scale") + correct weighing steps to determine actual mass of $NaHCO_3$ added into the cup. {step 2 & 8}
- Measure volume of HC*l*(aq) using an appropriate accurate apparatus e.g. measuring cylinder.
- Measure the initial temperature of HC*l*(aq) before mixing. {4 & 5}
- State the time of mixing and take temperature measurements at fixed time-intervals (accept 10 s to 1 min) all the way to an appropriate end-time (≥ 10 min and with min 6 data points) {step 6 & 7}. Reject: measure "temperature change"

Penalise either the 4rd mk or the 5th mk if step 7 and 8 are reversed.

(ii) Sketch, on Fig. 4.1, the graph you would expect to obtain using the measurements you planned to make in **(c)(i)**.

Indicate how the maximum temperature change, ΔT_{max}, can be determined on the graph.



- Draws two lines
  - one horizontal line before time of mixing
  - one increasing line starting below the first line after time of mixing and does not increase above the first line
- indicates ΔT_{max} correctly at time of mixing.

Fig. 4.1

[2]

(d) Assume that:

$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H_1 = -26.7 \text{ kJ mol}^{-1}$

$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g) \quad \Delta H_2 = +24.2 \text{ kJ mol}^{-1}$

Use these values of ΔH_1 and ΔH_2 to determine a value for enthalpy change of reaction, ΔH_r, for decomposition of $NaHCO_3(s)$.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g) \qquad \Delta H_r$$

$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$

$+ 2HCl(aq)$ $2\Delta H_2$ ΔH_1 $+ 2HCl(aq)$

$2NaCl(aq) + 2H_2O(l) + 2CO_2(g)$

$\underline{\Delta H_r = 2\Delta H_2 - \Delta H_1}$

$= 2(+24.2) - (-26.7)$

$= \underline{+75.1} \text{ kJ mol}^{-1}$

[2]

(e) The maximum temperature change, ΔT_{max}, can also be determined by direct measurement of the initial temperature and the final temperature reached only. Explain why the graphical method is likely to give a more accurate value of ΔT_{max}, than the direct measurement method.

ΔT_{max} obtained by the graphical method is more accurate as **<u>heat gained from surroundings has been accounted for</u>** (or **<u>heat-gain correction has been done</u>**) by the extrapolating the heating curve to the time of mixing.
Reject: "temp./heat correction".

[1]

[Total: 16]

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 Aqueous Anions

Anion	***Reaction***
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
choride, 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 on warming with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

(c) Tests for Gases

gas	***Test and test results***
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 acidified aqueous 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