ANDERSON SERANGOON JUNIOR COLLEGE

2021 JC 2 PRELIMINARY EXAMINATION

NAME:__________________________ (   ) **CLASS:** 21 /____

CHEMISTRY **9729/04**

Paper 4 Practical **26 August 2021**

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 27 and 28.

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	/ 13
2	/ 10
3	/ 18
4	/ 14
Total	/ 55

This document consists of **26** printed pages and **2** blank pages.

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

1 Determination of enthalpy change of reaction

FA 1 is solid potassium hydrogencarbonate, $KHCO_3$
FA 2 is 1.50 mol dm^{-3} sulfuric acid, H_2SO_4

(I) $KHCO_3(s) + aq \rightarrow K^+(aq) + HCO_3^-(aq)$ $\Delta H_{sol}(KHCO_3)$

The molar enthalpy change of solution of solid potassium hydrogencarbonate is the enthalpy change when one mole of solid potassium hydrogencarbonate dissolves in sufficient water such that the ions are well separated as shown in **(I)**.

When added to water, solid potassium hydrogencarbonate quickly dissolves and the temperature of the mixture falls.

(II) $KHCO_3(aq) + \frac{1}{2}H_2SO_4(aq) \rightarrow \frac{1}{2}K_2SO_4(aq) + H_2O(l) + CO_2(g)$ $\Delta H_r(KHCO_3(aq))$

The molar enthalpy change of reaction of aqueous potassium hydrogencarbonate with sulfuric acid in **(II)** is the enthalpy change when one mole of aqueous potassium hydrogencarbonate reacts with excess sulfuric acid.

You are to perform experiments by which you will determine the enthalpy change $\Delta H_{sol}(KHCO_3)$.

You will also determine the enthalpy change $\Delta H_r(KHCO_3(aq))$ using the data provided before using your results in a Hess's Law calculation.

(a) Follow the instructions below to determine the maximum temperature change when a known mass of solid potassium hydrogencarbonate, **FA 1**, dissolves completely in water.

In an appropriate format in the space provided below, record

- all weighings to an appropriate level of precision,
- all values of temperature to an appropriate level of precision.

1. Weigh the capped bottle containing **FA 1**.
2. Place one polystyrene cup inside a second polystyrene cup. Place these in a glass beaker to prevent them from tipping over.
3. Use a measuring cylinder to transfer 50 cm^3 of deionised water into the first polystyrene cup.
4. Stir the water in the cup with the thermometer. Read and record its temperature.
5. Transfer all the **FA 1** to the polystyrene cup. Stir the mixture.
6. Continue to stir the mixture. Observe the temperature and record the value that shows the maximum change from the initial temperature.
7. Reweigh the empty bottle and its cap.

Determine the maximum temperature change and the mass of **FA 1** used.

Results

[5]

(b) In the following calculations, you should assume that the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}, and the density of the solution is 1.00 g cm^{-3}.

(i) Use your results from **1(a)** to calculate the heat change for your experiment.

heat change = ... [1]

(ii) Hence, determine a value for $\Delta H_{sol}(KHCO_3)$.

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

[A_r: H, 1.0; C, 12.0; O, 16.0; K, 39.1]

$\Delta H_{sol}(KHCO_3)$ = ... [1]

The results of an experiment where a solution of aqueous potassium hydrogencarbonate, $KHCO_3(aq)$, similar to the one you have prepared in **1(a)**, was reacted completely with an excess of dilute sulfuric acid, **FA 2**, are shown in Table 1.1.

Table 1.1

mass of $KHCO_3(s)$ used / g	3.450
volume of $KHCO_3(aq)$ used / cm^3	50.0
initial temperature of $KHCO_3(aq)$ / °C	27.4
volume of **FA 2** used / cm^3	25.0
initial temperature of **FA 2** / °C	31.0
minimum temperature reached / °C	28.2

(iii) Use the results given in Table 1.1 and the formula below to calculate the weighted average initial temperature, T_{av}, of the reaction mixture.

The formula for T_{av} is given as

$$T_{av} = \frac{(\text{vol. of } \textbf{FA 2} \times \text{initial temp. of } \textbf{FA 2}) + (\text{vol. of } KHCO_3 \times \text{initial temp. of } KHCO_3)}{\text{total volume of reaction mixture}}$$

T_{av} = ... [1]

(iv) Hence, calculate a value for $\Delta H_r(KHCO_3(aq))$.

$\Delta H_r(KHCO_3(aq))$ = ... [3]

(c) Molar enthalpy change for the reaction of dilute sulfuric acid with solid potassium hydrogencarbonate is as shown.

$$2KHCO_3(s) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l) + 2CO_2(g) \quad \Delta H_r(KHCO_3(s))$$

Use your answers from **1(b)(ii)** and **1(b)(iv)** to determine a value for $\Delta H_r(KHCO_3(s))$.

If you are not able to determine a value for **1(b)(ii)** and/or **1(b)(iv)**, you may use x and y to represent the respective enthalpy changes and proceed with this part of the question.

$\Delta H_r(KHCO_3(s))$ = ... [2]

[Total: 13]

2 Planning

Magnesium sulfate, $MgSO_4$ is commonly used in instant hot packs. The hot pack is made up of water surrounding a pouch containing the salt. When the pack is squeezed, this inner pouch is broken, releasing the salt, which quickly dissolves and increases the pack's temperature.

The solubility of magnesium sulfate at 20 °C is about 0.292 mol per 100 cm^3.

A student decided to conduct an experiment to find out the molar enthalpy change of solution of magnesium sulfate by adding a known quantity of solid magnesium sulfate to water.

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 the molar enthalpy change of solution, ΔH_{sol}, for magnesium sulfate may be determined.

In this question, you are to plan a procedure that would provide sufficient data to allow you to determine an accurate and reliable value for the molar enthalpy change of solution, ΔH_{sol}, for magnesium sulfate.

(a) The literature value for the molar enthalpy change of solution of magnesium sulfate is found to be approximately –78.9 kJ mol^{-1}.

You may assume that 4.3 J are required to raise the temperature of 1.0 cm^3 of any solution by 1 °C.

Suggest a suitable volume of water you would use in this experiment and hence, calculate the **minimum** mass of solid magnesium sulfate required to ensure a ΔT_{max} of at least 5 °C.

[M_r $MgSO_4$: 120.4]

volume of water used = ... cm^3

minimum mass of solid $MgSO_4$ = ... g

[2]

(b) Plan an investigation to determine the maximum temperature change, ΔT_{max}, graphically for the dissolution of magnesium sulfate.

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:
- 50 g of magnesium sulfate,
- the equipment normally found in a school or college laboratory.

In your plan, you 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 ΔT_{max} is obtained.

[5]

(c) Sketch, on Fig. 2.1, the graph you would expect to obtain using the measurements you planned to make in **2(b)**.

Show, in your sketch, how the maximum temperature change, ΔT_{max}, can be determined.

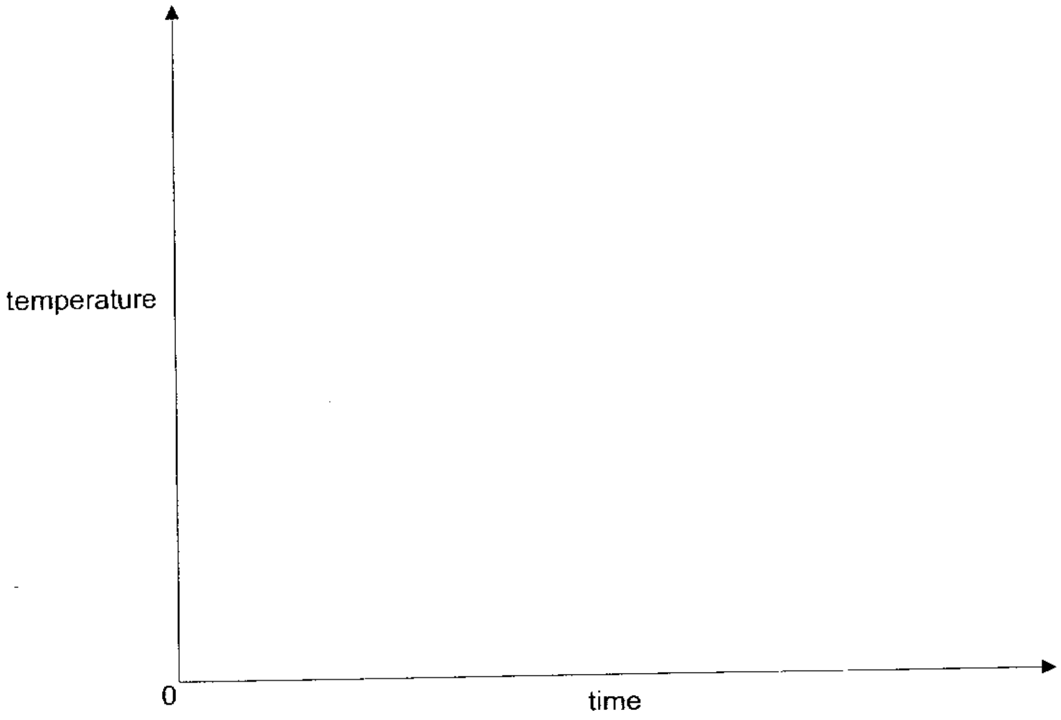

Fig. 2.1

[3]

[Total: 10]

Question 3 starts on the next page.

3 Investigation of reaction between manganate(VII) ions and X^{2-} ions

FA 2	1.5 mol dm^{-3} sulfuric acid, H_2SO_4
FA 3	0.0100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$
FA 4	0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$
FA 5	solution containing 0.200 mol dm^{-3} $\mathbf{X}^{2-}$ ions
FA 6	0.100 mol dm^{-3} potassium iodide, KI

A starch indicator is provided.

Acidified potassium manganate(VII) reacts with $\mathbf{X}^{2-}$, and iodide ions, I^- as shown in **equation 1** and **2** respectively. The Mn^{2+} ions produced in **equation 1** act as a catalyst for the reaction. This is an example of 'autocatalysis'.

$2MnO_4^-(aq) + 5\mathbf{X}^{2-}(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l)$ + other products **(equation 1)**

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

You will prepare an acidified solution of $\mathbf{X}^{2-}$ ions and you will add to this a solution of potassium manganate(VII). At timed intervals, you will withdraw five aliquots (portions) of the reaction mixture. The concentration of MnO_4^- ions in each aliquot will be determined after adding the aliquot to an excess potassium iodide solution and titrating the iodine produced against sodium thiosulfate (**equation 3**).

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

The results obtained will be graphically analysed.

You should read all the instructions on this page and the next 2 pages before you start the experiment.

(a) Preparing and titration of the reaction mixture

Note:
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 **not** to exceed a maximum reaction time of 15 minutes for this experiment.

In an appropriate format in the space provided on page 14, prepare a table in which 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 33s 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 about 10 cm^3 of **FA 6** to each of the 5 labelled boiling tubes, **1** to **5**.

3. Using appropriate measuring cylinders, add the following to the conical flask labelled **reaction mixture.**
    - 50.0 cm^3 of **FA 5**
    - 5.0 cm^3 of **FA 2**
    - 45.0 cm^3 of deionised water

4. Using a separate measuring cylinder, add 25.0 cm^3 of **FA 4** to this measuring cylinder.

5. Pour the **FA 4** into the conical flask labelled **reaction mixture**. Start the stopwatch and swirl the mixture thoroughly.

6. At approximately one minute, use a 10.0 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. Read and record time of transfer in minutes and seconds, to the nearest second, when half of the reaction mixture has emptied from the pipette.

7. At approximately two minutes, repeat step 6. Transfer this aliquot into the boiling tube labelled **2**.

8. Repeat step 7 **three** more times at about three minutes intervals, transferring the aliquots into the boiling tubes labelled **3** to **5**.

9. Pour the content of boiling tube **1** into a clean 250 cm^3 conical flask. Wash out this boiling tube and add the washing to the conical flask.

10. Titrate the iodine in this solution with **FA 3**. When the colour of the solution turns pale yellow, add about 1 cm^3 of starch indicator. The solution will turn blue–black. Continue the titration. The end–point is reached when the blue–black colour just disappear. Record your results.

11. Wash this conical flask thoroughly with water. Refill the burette with **FA 3** if necessary.

12. Repeat steps 9 to 11 as required for each of the remaining boiling tubes.

Results

[3]

(b) **(i)** On the grid below, plot a graph of the volume of **FA 3** used, on the y–axis, against decimal time, t_d, on the x–axis in the grid.

Draw the most appropriate best–fit curve taking into account all of your plotted points.

[3]

(ii) Consider the shape of the graph in **(b)(i)**.
Describe the shape and explain how it relates to the rate of **equation 1**.

....

....

....

....

....[2]

(iii) Suggest why manganese(II) sulfate can catalyse the reaction between $\mathbf{X}^{2-}$ and manganate(VII) ions.

Equations showing the stages in the catalysed reaction are **not** required.

....

....

....

....

....[2]

Question 3 continues on the next page.

(c) In another reaction, acidified hydrogen peroxide oxidises iodide ion, I^- as shown in **equation 4**. It is known that this reaction is first order with respect to iodide ions and zero order with respect to hydrogen ions.

$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$ **(equation 4)**

In order to obtain the order of reaction with respect to hydrogen peroxide, a student conducted an experiment where he extracted 10.0 cm^3 aliquots of a reaction mixture, containing 50.0 cm^3 of hydrogen peroxide, 25.0 cm^3 of iodide ions (in excess) and 25.0 cm^3 of hydrogen ions (in excess), at regular time intervals. He did this by first removing iodide ions in each aliquot through quenching and then titrating the hydrogen peroxide present with 0.010 mol dm^{-3} potassium manganate(VII), $KMnO_4$ as shown in **equation 5**.

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

The results of his experiment are shown in Fig 3.2.

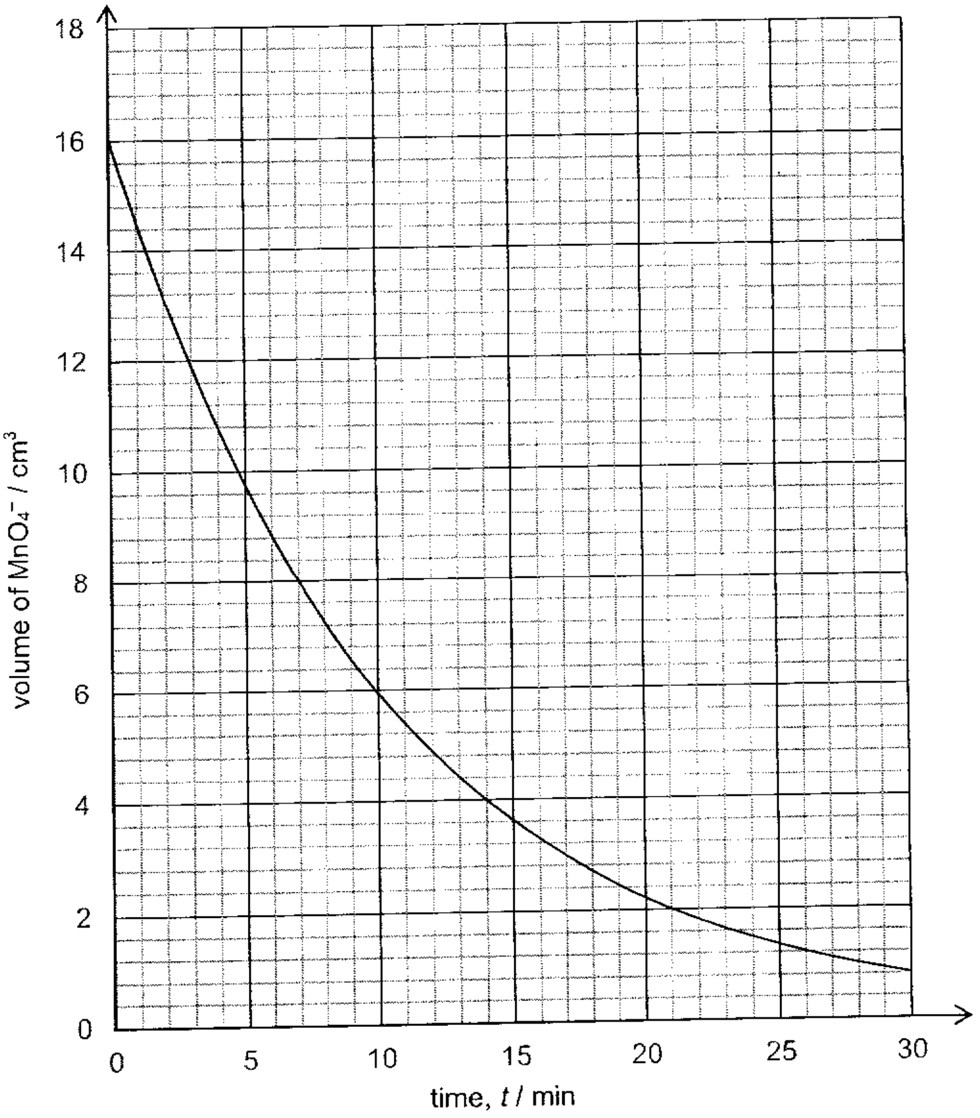

Fig. 3.2

(i) Use data from the graph in Fig. 3.2 to show that the reaction in **equation 4** is first order with respect to $[H_2O_2]$.

....

....

....

....[2]

The rate of change of the concentration of hydrogen peroxide, $[H_2O_2]$ at time $t = 15$ min can be determined from the gradient of the tangent to the graph line.

(ii) Draw a tangent to your graph line at time $t = 15$ min. Determine the gradient of this line, showing clearly how you did this.

gradient = ... $cm^3\ min^{-1}$ [2]

(iii) Use the gradient obtained in **(c)(ii)** 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]

(iv) Hence, calculate the rate of depletion of H_2O_2 in mol min^{-1}.

rate of depletion of H_2O_2 = ...mol min^{-1} [1]

(v) Use your answer to **(c)(iv)** to calculate the rate of change of [H_2O_2], in the reaction mixture at time *t* = 15 min.

rate of change of [H_2O_2] = ... mol dm^{-3} min^{-1} [2]

[Total: 18]

4 **Investigation of some inorganic reactions**

In this question, the **name** or **correct formula** of the element or compound must be given where reagents are selected for use in a test.

At each stage of any test, you are to record details of the following:

- colour change seen,
- the formation of any precipitate and its solubility in an excess of the reagent added,
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test–tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

(a) **FA 7** is a binary salt consisting of two ions, both of which are listed in the Qualitative Analysis Notes on pages 27 and 28.

(i) Place a small spatula measure of **FA 7** into a hard–glass boiling tube.

Heat the tube gently at first for 1 minute and then more strongly for another 2 minutes. Record **all** your observations.

....

....

....

....

....[2]

(ii) Dissolve a spatula of **FA 7** in a 5 cm depth of distilled water in a boiling tube. This solution you have prepared is known as **FA 7(aq)**. You will need this solution for subsequent parts of this question.

Transfer about 1 cm depth of this solution into a test–tube for use in **Test I**. Record your observation in Table 4.1.

Test II has been conducted and the observation was recorded in Table 4.1.

Keep the remainder of FA 7(aq) for use in 4(b)(ii).

Table 4.1

test	*observations*
Test I Add aqueous sodium hydroxide to the test–tube containing 1 cm depth of **FA 7(aq)**.	
Test II Add a 1 cm depth of aqueous hydrogen peroxide to the test–tube containing 1 cm depth of **FA 7(aq)**, then add aqueous sodium hydroxide.	Effervescence observed. Gas evolved rekindled a glowing splint. Dark brown ppt. insoluble in excess NaOH(aq).

[2]

(b) **FA 8** is a solution containing a different salt. The cation present in **FA 8** is not listed in the Qualitative Analysis Notes on pages 27 and 28.

(i) **FA 7(aq)** and **FA 8** each contains either a halide ion or an anion containing sulfur. Both anions are listed in the Qualitative Analysis Notes on pages 27 and 28.

Describe **two different** tests, using only the bench reagents provided, which will allow you to distinguish between them.

In each case, state how you will decide if the test result is positive.

test 1 ....

....

....

test 2 ....

....

....

[2]

(ii) Perform the tests you described in **(b)(i)** using the **FA 7(aq)** you have prepared in **4(a)(ii)** and the **FA 8** provided.

Record your observations below.

test 1 ....

....

....

test 2 ....

....

....

[3]

(iii) Use your observations in **4(a)** and **4(b)(ii)** to identify the ions present in **FA 7** and **FA 8**.

Write the formula of the ions in Table 4.2. You are **not** required to identify the cation present in **FA 8**.

Table 4.2

	FA 7	**FA 8**
cation		
anion		

[3]

(iv) Suggest what you would observe if aqueous chlorine was added to separate portions of **FA 7(aq)** and **FA 8**.

Aqueous chlorine and **FA 7(aq)**	
Aqueous chlorine and **FA 8**	

[2]

[Total: 14]

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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

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 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 on warming 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

2021 H2 Chemistry Paper 4 Suggested Solution

<table>
<tr><th>Qn</th><th>Teaching points</th><th>Marks</th></tr>
<tr><td>**1(a)**</td><td>
<table>
<tr><td>mass of capped bottle and **FA 1** / g</td><td>7.378</td></tr>
<tr><td>mass of capped bottle and residual **FA 1** / g</td><td>3.488</td></tr>
<tr><td>mass of **FA 1** used / g</td><td>3.490</td></tr>
</table>
<table>
<tr><td>initial temperature / °C</td><td>28.8</td></tr>
<tr><td>lowest / minimum temperature reached / °C</td><td>24.8</td></tr>
<tr><td>decrease in temperature / maximum change in temperature / °C</td><td>4.0</td></tr>
</table>
</td><td></td></tr>
<tr><td></td><td>

May record data in a single table or have one table for mass and one table for temperature; Tabulation may be vertical or horizontal; lines are not essential
For “temperature drop” allow “temperature change” sign not essential as it will be accounted for later in the sign for the enthalpy change.

[1]: correct headers and units.
[1]: mass readings to 3 d.p. and temperature readings to 1 d.p.
[1]: correctly determined maximum temperature change and mass of **FA 1** used
</td><td>[3]</td></tr>
<tr><td></td><td>
Accuracy marks compare student's and teacher's $\frac{\Delta T}{m}$
</td><td>[2]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>**(b)(i)**</td><td>Calculate heat change using result from 1(a)

Heat change (q_1) = mcΔT
= (50 x 1.00) x 4.18 x (temp drop)
= ________ J</td><td>[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>**(b)(ii)**</td><td>Determine value of $\Delta H_{sol}(KHCO_3)$ with correct sign

$\Delta H_{sol}(KHCO_3)$ = + (q_1) / n($KHCO_3$)
= + ________ J mol^{-1}</td><td>[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>**(b)(iii)**</td><td>Calculate correctly initial T_{av} = 28.6 °C</td><td>[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>**(b)(iv)**</td><td>Heat change (q_2) = mcΔT
= (25+50) x 1.00 x 4.18 x (28.6 – 28.2)
= 125.4 J

$\Delta H_r(KHCO_3(aq))$ = + (125.4) / (3.450/100.1)
= +3640 J mol^{-1}

Final answer to 3 s.f. or 4 s.f. and appropriate units for **(b)(i)**, **(b)(ii)**, **(b)(iii)** and **(b)(iv)**.</td><td>[1]

[1]

[1]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

(c)	$\begin{tikzcd} 2KHCO_3(aq) + H_2SO_4(aq) \arrow[rr, "2 \text{ x } [1(b)(iv)]"] & & K_2SO_4(aq) + 2H_2O(l) + 2CO_2(g) \\ & 2KHCO_3(s) + H_2SO_4(aq) \arrow[ul, "2 \text{ x } [1(b)(ii)]"] \arrow[ur, "\Delta H_r(KHCO_3(s))"'] & \end{tikzcd}$ $2 \text{ x } [1(\mathbf{b})(ii)] + 2 \text{ x } [1(b)(iv)] = \Delta H_r(KHCO_3(s))$ $= \_\_\_\_\_\_\_\_ \text{ J mol}^{-1}$ [1]: correct application of Hess' Law [1]: correct answer; awarded only if **(b)(ii)** and **(b)(iv)** are correct and applied correctly (ignore units)	[2]

Qn	Teaching points	Marks

2(a)

Preliminary Calculations

- Calculate the mass of $MgSO_4$ to use for the experiment.
- Assuming that **<u>100 cm³ of water</u>** was used in the experiment and a temperature change of
5 °C is measured and no heat loss to surroundings, [1]

$n_{salt} \times 78.9 \times 10^3 = 100 \times 4.3 \times 5 \Rightarrow n_{salt} = 0.02724$ mol [1]
minimum mass of $MgSO_4$ to use = 0.02724 x 120.4 = 3.28 g

Given the solubility of $MgSO_4$ at 20 °C = 0.292 mol per 100 cm^3
maximum mass that can dissolve in 100 cm^3 of water = 0.292 x 120.4 = 35.2 g

Hence a mass of about 10 g of $MgSO_4$ can be used for the experiment.

(10 g of $MgSO_4$ is a suitable mass as it can be easily measure and from the above preliminary calculations, we know that this mass chosen will be able to give a temperature rise of about 5°C and will completely dissolve in 100 cm^3 of water.)

Marking consideration

- for min and max temp
- for proposed mass

Expt	Assumed volume of water/cm³	heat needed/ J	nsalt	Min Mass of solid/g	Max Mass of solid/g
1	50	1075	0.01362	1.6404	17.5784
2	100	2150	0.02725	3.2809	35.1568
3	150	3225	0.04087	4.9213	52.7352
4	200	4300	0.05450	6.5617	70.3136
5	25	537.5	0.00681	0.8202	8.7892
6	75	1612.5	0.02044	2.4606	26.3676
7	125	2687.5	0.03406	4.1011	43.946

<u>No marks</u> will be **<u>deducted</u>** for **<u>wrong/no</u>** determination of **<u>max mass</u>** of $MgSO_4$ used since students will be penalized in (b)
<u>No marks awarded</u> if only the volume of water used is quoted with NO workings to determine mass of solid.

(b)

General outline of experiment

1. Using an electronic balance, weigh accurately 10.000 g of $MgSO_4$ into a pre-weighed dry weighing bottle.
2. Record the mass of $MgSO_4$ and the bottle in the table.
3. Using a 100 cm^3 measuring cylinder, transfer 100 cm^3 of **water** into a dry Styrofoam cup, placed in a 250 cm^3 beaker.
4. Place the lid on the cup, slip the thermometer through the lid and stir the water gently using the thermometer.
5. Start the stop-watch and record the initial temperature of the water. Record the temperature of the water every 30s for 2.5 min.
6. At exactly 3 min, add the $MgSO_4$ in the weighing bottle to the Styrofoam cup. Cover the cup with a lid and continue to stir the mixture gently with the thermometer and record the temperature every 30s from 3.5 min to 10.0 min.
7. Reweigh the weighing bottle and record the actual mass of $MgSO_4$ that dissolved in water.
8. Plot graph of temperature against time
9. Extrapolate the graph to the third minute when $MgSO_4$ was added to water to obtain the highest temperature reached

Marking consideration:
Correct mention of electronic balance, measuring cylinder, Styrofoam cup, beaker, thermometer
Logical mass of $MgSO_4$ used. (between 3.28 g and 35.2 g)
Starting the stop-watch and measuring the temperature of water for a few minutes before adding $MgSO_4$ into the water
Showing understanding of reweighing the weighing bottle to obtain the accurate mass transferred
Ensuring accurate and reliable value of ΔT_{max} is obtained

Apparatus	Procedure	Graph	Reliability
A1	P1/ P2	G1	R1
1. Electronic/ weighing + balance/ scale/ machine 2. (weighing) bottle (reject: small beaker/ container/ bottle cap) 3. measuring cylinder 4. Styrofoam/ Polystyrene cup (Reject: cup) 5. Thermometer Any 4 will do. *capacity not needed	1. Corresponding mass of $MgSO_4$ used and volume of water from (a) (Mass of solid must be < 50g) (If no mass value determined, accept any value <50g) 2. Starting the stop-watch. 3. Record temperature of water for a few minutes **BEFORE** adding $MgSO_4$ into the water. 4. Add solid (at t = ?) 5. Record temperature of water for a few minutes **AFTER** adding $MgSO_4$ into the water. 6. Reweigh the weighing bottle (All – P2, Only 3 points- P1) P=0 once solid is already in the cup.	1. Plot graph of temperature against time 2. Extrapolate the graph to the third minute (time of addition) when $MgSO_4$ was added to water to obtain the highest temperature reached. (Both)	1. Dry weighing bottle 2. Stir the water 3. Styrofoam cup in beaker 4. Cup covered by lid. Any 2.

Annotation A: apparatus, **P:** procedure **R:** Reliability

<table>
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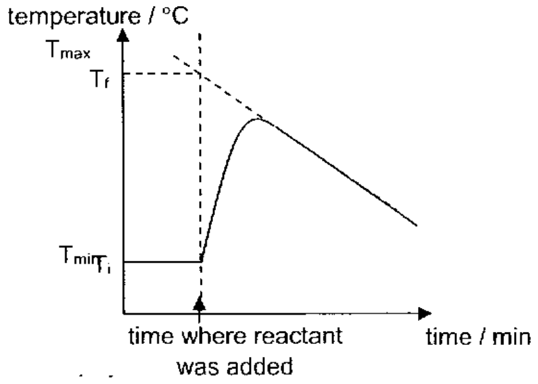
<tr><td>(c)</td><td>


Correct shape showing graph before and after addition of $MgSO_4$. [1]
Correct extrapolation of graph [1] (allow ecf if endo graph is shown)
Indicate clearly, minimum temperature, maximum temperature and ΔT on graph [1] (allow ecf if endo graph is shown)
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</table>

Qn	Teaching points	Marks
3(a)	Table to include with correct headers and units: • Time of transfer (about 1 min, 2 min, 5 min, 8 min, 11 min and 14 min) • Decimal time • Initial and final burette readings • Volume of **FA 3** added Table need not be populated. Table may be horizontal or vertical and lines are not essential but there should be no absence of headers. Appropriate unit for each entry in the table if no units in the header. Can be separate tables.	[1]
	Record **all** • Burette readings and volumes added to 0.05 cm^3 • Transfer times in minutes and seconds (to 1 s) • Correctly calculated values of decimal time • Decimal time to 0.1 min	[1]
	5 sets of result and are transferred within ± 30 seconds of the suggested times.	[1]
(b)(i)	Correct axes, labels and units; scale uses over half the graph paper in both axes. Do not award this mark if an awkward scale (e.g recurring or each big square is 3, 6 etc) is used that makes plotting/reading difficult. Ignore dp of axes (e.g 5, 5.0, 5.00 all ok) Do NOT double penalize if the student has copied the same wrong units from the table.	[1]
	Plotting within ± ½ small square. Check two points – the 2nd and 4th point; put ticks if correct. If less than 5 plotted points – do not award this mark If more than 5 plotted points – can award if 2nd and 4th points are correct Ignore if the plotted points look too big or pencil too blunt. Plotted points are marked separately with shape of curve. Award even if best fit curve not drawn. If student's table ~~does~~ not include decimal time, calculate the decimal time for 2nd and 4th point and award accordingly.	[1]
	Draw a best fit, smooth curve (with correct shape) – accept only auto-catalysis graph. End of graph need not be flatten. Do not accept straight line, 1st order graph (concave or convex) even if points seems to suggest such shapes. Accept if graph touch or did not touch both axes. Do not allow if clearly anomalous points have been included. If the last timing on the X-axes is 6 min or less, allow concave curve.	[1]
(b)(ii)	Describe graph line as downward sloping curve with a gentle gradient at the start, then becoming steep in the middle, then gentle towards the end. Implies reaction begins slowly initially, then proceeds with a faster rate and subsequently slows down towards the end of the reaction.	[1] [1]
(b)(iii)	- Negatively charged MnO_4^- and X^{2-} ions repel each other - Results in **high E_a** for reaction	[1]

	- Electrostatic attraction between Mn^{2+} and the negative ions - Provides alternative pathway with **lower** E_a.	[1]
(c)(i)	Volume of of $KMnO_4$ is directly proportional to the concentration of H_2O_2 First order reaction w.r.t. H_2O_2, constant half-life. Construction line on the graph Indicate at least 2 values of $t_{½}$ on graph Do not accept if values are obtained from extrapolating graph on both ends.	[1] [1]
(c)(ii)	Gradient line touches the curve at the **t** = 15 min point **and** it is a tangent at this point. Do not allow this mark if the line is not tangential, does not touch the curve or covers/crosses part of the curve. Clear indication of **correct** co-ordinates from graph **or** correct values of volume and of time used (measured to ± ½ small square) and gradient correctly calculated	[1] [1]
(c)(iii)	Example using the gradient value of 0.3094 $cm^3\ min^{-1}$ $\rightarrow 0.3094 \div 1000 = 3.094 \times 10^{-4}\ dm^3\ min^{-1}$ Rate of change of the amount of MnO_4^- required $= 3.094 \times 10^{-4} \times 0.01$ $= 3.094 \times 10^{-6}$ $= 3.09 \times 10^{-6}$ mol min^{-1} (3s.f) *Student can use the units provided to understand the working based on the manipulation of the units* $\frac{mol}{dm^3} \times \frac{dm^3}{min}$ *where the first term is the concentration while the second term is the gradient* $cm^3\ min^{-1}$ *being converted to* $dm^3\ mol^{-1}$	[1]
(c)(iv)	Rate of depletion of $H_2O_2 = (3.094 \times 10^{-6}) \times \{5/2\}$ $= 7.735 \times 10^{-6}$ $= 7.74 \times 10^{-6}$ mol min^{-1} (3s.f.) Above calculation serve as a guide and should not be automatically used when marking this question. All calculation based on students' gradient value.	[1]
(c)(v)	$(7.735 \times 10^{-6}) \div (10 \times 10^{-3}) = 7.74 \times 10^{-4}$ mol $dm^{-3}\ min^{-1}$	[1] [1]

Qn	Teaching points	Marks
(a)(i)	Any **three** observations on heating **FA 7**: □ initially pink crystals □ (on gentle heating) solid turns white / paler (pink) □ condensation / water droplets / water vapour / misty fumes ₁ □ (gas) turns (damp blue) **litmus** red □ melts / liquid formed / dissolves □ (solid / liquid) turns brown / ochre / yellow-brown ₂ □ residue is dark brown / black **solid** ₃ ₁ Allow steam ₂ Reject red-brown ₃ Reject ppt Ignore bubbles of gas Ignore incorrect positive gas tests	[2]
(a)(ii)	Off-white ppt, rapidly turn brown on contact with air Insoluble in excess NaOH(aq)	[1] [1]
(b)(i)	Selects for halide: (aqueous) $AgNO_3$ / silver nitrate **and** (followed by) NH_3 / (aqueous) ammonia Ignore preliminary use of nitric acid.	[1]
	Selects for anion containing sulfur: (aqueous) $BaCl_2$ / $Ba(NO_3)_2$ or names **and** HCl / HNO_3 or names Reject if use of sulfuric acid is shown.	[1]
	If neither mark is awarded, allow 1 mark for: *$AgNO_3$ / silver nitrate – halide* ***AND** $BaCl_2$ / $Ba(NO_3)_2$ (or name) – S-anion* *Reject if use of sulfuric acid with Ba^{2+} salt is shown.*	
(b)(ii)	Expected observations:	[3]

	FA7 (aq)	FA8
+ Ag^+	white ppt *	(pale) yellow ppt *
+ NH_3	(ppt) colour darkens / off-white / buff / beige / pale brown *	(ppt) insoluble *
+ Ba^{2+}	no change / no ppt / no reaction / not needed *	no change / no ppt / no reaction / not needed *
+ H^+	ignore	ignore

Two * = 1 mark (round down).
Allow 1 mark for the following observations with NH_3(aq) if $AgNO_3$(aq) was not selected:
FA 7 (aq): off-white / beige / buff / pale / light brown ppt
AND
FA 8: no reaction

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<tr><td>(b)(iii)</td><td><table>
<tr><td></td><td>FA7</td><td>FA8</td></tr>
<tr><td>cation</td><td>Mn^{2+}</td><td>unknown</td></tr>
<tr><td>anion</td><td>Cl^-</td><td>I^-</td></tr>
</table>
Ignore K^+ of FA9
Allow names (manganese (II), chloride, iodide)</td><td>[3]</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>(b)(iv)</td><td>FA 7 + Cl_2: no reaction / no (visible) change
Allow turns black / dark brown if Mn^{2+} identified.</td><td>[1]</td></tr>
<tr><td></td><td>FA 8 + Cl_2: solution turns yellow / brown or black / dark grey ppt
Allow ecf for bromide for either (not both) FA 7 or FA 8:
solution turns yellow / red-brown / brown.
Allow solution turns orange for either Br^- or I^-.
Allow no reaction / no (visible) change if SO_3^{2-} / SO_4^{2-} identified.</td><td>[1]</td></tr>
</table>