ANDERSON SERANGOON JUNIOR COLLEGE

2021 JC 2 PRELIMINARY EXAMINATION

NAME:	()	CLASS: 21 /

CHEMISTRY

Paper 4 Practical

9729/04 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.

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	/ 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, KHCO₃
FA 2 is 1.50 mol dm⁻³ sulfuric acid, H₂SO₄

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

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 cm³ 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

- (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]

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

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

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

*T*_{av} =[1]

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

∠*H*_r(KHCO₃(aq)) =[3]

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

 $2\mathsf{KHCO}_3(\mathsf{s}) + \mathsf{H}_2\mathsf{SO}_4(\mathsf{aq}) \to \mathsf{K}_2\mathsf{SO}_4(\mathsf{aq}) + 2\mathsf{H}_2\mathsf{O}(\mathsf{I}) + 2\mathsf{CO}_2(\mathsf{g}) \quad \Delta H_r(\mathsf{KHCO}_3(\mathsf{s}))$

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.

[Total: 13]

2 Planning

Magnesium sulfate, MgSO₄ 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 cm³.

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 MgSO₄: 120.4]

v	olume of water used	=	 cm ³
minimu	m mass of solid MgS	O 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.

9

.....

[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.





[3]

[Total: 10]

Question 3 starts on the next page.

3 Investigation of reaction between manganate(VII) ions and X²⁻ ions

- **FA 2** 1.5 mol dm⁻³ sulfuric acid, H₂SO₄
- **FA 3** 0.0100 mol dm⁻³ sodium thiosulfate, $Na_2S_2O_3$
- **FA 4** 0.0200 mol dm⁻³ potassium manganate(VII), KMnO₄
- **FA 5** solution containing 0.200 mol dm⁻³ X²⁻ ions
- **FA 6** 0.100 mol dm⁻³ potassium iodide, KI

A starch indicator is provided.

Acidified potassium manganate(VII) reacts with X^{2-} , and iodide ions, I⁻ as shown in equation 1 and 2 respectively. The Mn²⁺ ions produced in equation 1 act as a catalyst for the reaction. This is an example of 'autocatalysis'.

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

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

You will prepare an acidified solution of 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 cm³ 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 cm³ of **FA 5**
 - 5.0 cm³ of **FA 2**
 - 45.0 cm³ of deionised water
- 4. Using a separate measuring cylinder, add 25.0 cm³ 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 cm³ pipette to remove a 10.0 cm³ 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 cm³ 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 cm³ 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

(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 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.

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

In order to obtain the order of reaction with respect to hydrogen peroxide, a student conducted an experiment where he extracted 10.0 cm³ aliquots of a reaction mixture, containing 50.0 cm³ of hydrogen peroxide, 25.0 cm³ of iodide ions (in excess) and 25.0 cm³ 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), KMnO₄ 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 $[H_2O_2]$.

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]

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.

(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).

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).

Table 4.1

[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.

(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.

 (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]

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[Total: 14]

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Qualitative Analysis Notes [ppt. = precipitate]

(a) Reactions of aqueous cations

aatian	reaction with		
calion	NaOH(aq)	NH₃(aq)	
aluminium,	white ppt.	white ppt.	
Al ³⁺ (aq)	soluble in excess	insoluble in excess	
ammonium, NH₄⁺(aq)	ammonia produced on heating	_	
barium, Ba²⁺(aq)	no ppt. (if reagents are pure)	no ppt.	
calcium, Ca²⁺(aq)	white ppt. with high [Ca ²⁺ (aq)]	no ppt.	
chromium(III).	grey–green ppt.	grev–green ppt.	
Cr ³⁺ (aq)	soluble in excess giving dark green solution	insoluble in excess	
copper(II).	pale blue ppt.	blue ppt.	
Cu ²⁺ (aq)	insoluble in excess	soluble in excess	
	groop ppt, turning brown on contact	group and turning brown on contact	
iron(II),	with air	with air	
Fe ²⁺ (aq)	insoluble in excess	insoluble in excess	
iron(III),	red-brown ppt.	red-brown ppt.	
Fe ³⁺ (aq)	insoluble in excess	insoluble in excess	
magnesium,	white ppt.	white ppt.	
Mg ²⁺ (aq)	insoluble in excess	insoluble in excess	
manganese(II),	off-white ppt., rapidly turning brown	off-white ppt., rapidly turning brown	
Mn ²⁺ (aq)	insoluble in excess	insoluble in excess	
zinc	white pot	white not	
Zn ²⁺ (aq)	soluble in excess	soluble in excess	

(b) Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, C <i>l</i> ⁻(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 NH₃(aq))
nitrate, NO₃⁻(aq)	NH_3 liberated on heating with $OH^-(aq)$ and Al foil
nitrite, NO₂⁻(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, SO₄²⁻(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, NH₃	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, I2	black solid / purple gas	brown	purple