

# TAMPINES MERIDIAN JUNIOR COLLEGE

# PRELIMINARY EXAMINATION

CANDIDATE NAME

CIVICS GROUP

# H2 CHEMISTRY

Practical

# 9729/04 29 August 2023

2 hours 30 minutes

Candidates answer on the Question Paper.

## **READ THESE INSTRUCTIONS FIRST**

Write your name and Civics Group in the spaces at the top of the page.

Give details of the practical shift and laboratory where appropriate, in the boxes provided.

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 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 20 and 21.

The number of marks is given in brackets [] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use		
1	/ 11	
2	/ 16	
3	/ 17	
4	/ 11	
Total	/ 55	

This document consists of **21** printed pages.



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

#### 1 Investigation of organic and inorganic compounds

(a) FA 1, FA 2, FA 3 and FA 4 are aqueous solutions known to be hydrochloric acid, ethanoic acid, methanoic acid and sulfuric acid. All the solutions have the same concentration.

Note: the order of FA 1 to FA 4 does not correspond to the order of identities given above.

(i) Carry out the following tests for **FA 1** to **FA 3**. Record your observations in Table 1.1.

Observations for **FA 4** have already been recorded in Table 1.1. There is no need to carry out the tests for **FA 4**.

The volumes given below are approximate and should be estimated rather than measured.

Test and identify any gases evolved.

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



~
- 5
J
-

Table 1.1

toot		observ	vations	
test	FA 1	FA 2	FA 3	FA 4
<ol> <li>Add about 2 cm depth of FA 1 in a test-tube. Add a piece of magnesium into FA 1.</li> <li>Repeat using FA 2 and FA 3, in place of FA 1.</li> </ol>				There is slower effervescence observed. Gas evolved "pops" with a lighted splint. Gas is hydrogen.
<ul> <li>2. To a 1 cm depth of dilute sulfuric acid in a test-tube, add 2 drops of aqueous potassium manganate(VII). Then add 2 cm depth of FA 1.</li> <li>Place the test-tube in a hot water bath.</li> <li>Repeat using FA 2 and FA 3, in place of FA 1.</li> </ul>				No observable change.

[3] M3

[Turn over

M1



- (ii) Complete Table 1.2 with the identities of **FA 3** and **FA 4**. Give evidence from the observations in Table 1.1 to support your conclusions.

	identity	evidence		
FA 3				
FA 4				M4
	•	·		M5
			[2]	

Table 1.2

(iii) Carry out **one** additional test that allows you to distinguish between **FA 1** and **FA 2**. Your tests should be based on the Qualitative Analysis Notes on pages 20–21 and should use only the bench reagents provided. Record your tests and observations in the space below.

FA 1 is	3	 	 
<b>FA 2</b> is	S	 	 



(b) In this question, you will investigate the chemistry of vanadium ions.

**FA 5** contains vanadate(V) ions,  $VO_3^{-}$ .

When **FA 5** is acidified and reacted with a metal M, a series of colour changes can be observed during the reaction.

You will carry out tests to study the reaction of acidified **FA 5** with the metal **M**. Record your observations in Table 1.3.

In these reactions, you do **not** need to test for any gas that is evolved.

	Tests	Observations	1
(i)	Place 2 cm depth of <b>FA 5</b> into a boiling tube.		
	Add 4 cm depth of sulfuric acid to the same boiling tube. Mix well and record any colour changes that occur.		
(ii)	Using a spatula, add metal <b>M</b> , a very small amount (about half spatula) at each time, into the boiling tube. Swirl after each addition. You are required to make 4 additions of metal <b>M</b> . Note: it is important to add <b>M</b> in small amounts in order to obtain accurate observations. You may leave the mixture to stand,		
	swirling the boiling tube from time to time and observe the solution until no further changes are seen.		Me
Whi	le you are waiting, continue with the oth	er questions.	NI8
		-	M9
			[2]

#### Table 1.3

Electrode reaction	<i>E</i> ⇔/ V
$VO_3^- + 4H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$	+1.00
$VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O$	+0.34
$V^{3+} + e^- \rightleftharpoons V^{2+}$	-0.26
$V^{2+} + 2e^- \rightleftharpoons V$	-1.20

(c) The half equations that represent the stepwise reduction of  $VO_3^-$  ions are shown below.

The ions  $VO^{2+}$ ,  $V^{3+}$  and  $V^{2+}$  have different colours.

A student suggested that metal **M** could be platinum, silver or zinc.  $[E^{\ominus}_{Pt^{2^{+}}/Pt} = +1.18 \text{ V}; E^{\ominus}_{Ag^{+}/Ag} = +0.80 \text{ V}; E^{\ominus}_{Zn^{2^{+}}/Zn} = -0.76 \text{ V})]$ 

With reference to the  $E^{\ominus}$  values and your observations in test (ii) of Table 1.3, give two reasons why metal **M** is likely to be zinc.

M10 M11 [2]

[Total: 11]



### 2 Investigation of the effect of concentration on rate of reaction

In acidic solutions, iron(III) ions oxidise iodide ions,  $I^-$ , to iodine,  $I_2$ .

 $2Fe^{3+}(aq) + 2I^{-}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$ 

The rate of this reaction can be investigated by using starch indicator, which turns blue-black in the presence of iodine. Sodium thiosulfate is added to the reaction mixture to react with iodine as it is formed. The blue-black colour is seen when all the thiosulfate has reacted.

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

You will investigate how the rate of reaction is affected by changing the concentration of the iodide ions.

**FA 6** is 0.0500 mol dm<sup>-3</sup> potassium iodide, KI. **FA 7** is 0.0500 mol dm<sup>-3</sup> acidified iron(III) chloride, FeC $l_3$ . **FA 8** is 0.00500 mol dm<sup>-3</sup> sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>. **FA 9** is starch indicator.

#### You should read through the whole method before starting any practical work.

#### (a) Method

#### Experiment 1

- Fill a burette with **FA 6**.
- Run 20.00 cm<sup>3</sup> of **FA 6** into a 100 cm<sup>3</sup> beaker and place it on a white tile.
- Use a 50.0 cm<sup>3</sup> measuring cylinder to add the following to the same 100 cm<sup>3</sup> beaker:
   20 cm<sup>3</sup> of FA 8
  - $\circ$  10 cm<sup>3</sup> of **FA 9**
- Use the 10 cm<sup>3</sup> measuring cylinder labelled **FA 7** to measure 10.0 cm<sup>3</sup> of **FA 7**.
- Add this **FA 7** into the same 100 cm<sup>3</sup> beaker and start timing immediately.
- Stir the mixture once with a glass rod.
- Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in Table 2.1.
- Wash out the beaker and dry it with a paper towel. Rinse and dry the glass rod.

#### Experiment 2

- Run 10.00 cm<sup>3</sup> of **FA 6** into the 100 cm<sup>3</sup> beaker.
- Use a second 10.0 cm<sup>3</sup> measuring cylinder to add deionised water into the beaker containing **FA 6**.
- Use the 50.0 cm<sup>3</sup> measuring cylinder to add the following to the same 100 cm<sup>3</sup> beaker:
   20 cm<sup>3</sup> of FA 8
  - 10 cm<sup>3</sup> of FA 9
- Use the 10  $\text{cm}^3$  measuring cylinder labelled **FA 7** to measure 10.0  $\text{cm}^3$  of **FA 7**.
- Add this **FA 7** into the same 100 cm<sup>3</sup> beaker and start timing immediately.
- Stir the mixture once with a glass rod.
- Stop timing as soon as the solution turns blue-black. Ignore any colour changes that occur before the intense blue-black colouration.
- Record this reaction time to the nearest second in Table 2.1.
- Wash out the beaker and dry it with a paper towel. Rinse and dry the glass rod.

Experiments 3 and 4

Carry out two further experiments to investigate how the reaction time changes with different volumes of FA 6.
 The combined volume of FA 6 and deionised water must always be 20.0 cm<sup>3</sup>.
 Use volumes of FA 6 that are between 10.00 and 20.00 cm<sup>3</sup>.

#### Results

The rate of reaction can be calculated as shown:

rate =  $\frac{1000}{\text{reaction time}}$ 

Use this expression to calculate the rate for each of your experiments and record the values in Table 2.1. Give your answer to 3 significant figures.

Expt	volume of <b>FA 6</b> / cm <sup>3</sup>	volume of <b>FA 7</b> / cm <sup>3</sup>	volume of deionised water / cm <sup>3</sup>	reaction time / s	rate / s⁻¹
1					
2					
3					
4					





(b) On the grid in Fig. 2.1. below, plot a graph of rate of reaction against volume of **FA 6** added. Include the origin as one of your data points.

Draw a line of best fit. Label any points you consider anomalous.



Fig 2.1

[3]

(c) (i) Using data from **Experiments 1** and **2**, show by calculation that the volume of M17 aqueous potassium iodide, **FA 6**, used was directly proportional to the concentration of iodide ions.



(ii) Explain, with reference to the shape of your graph, how the rate of reaction is affected by an increase in the concentration of aqueous potassium iodide, **FA 6**.



- (d) A student carried out the same experiment but used 7.00 cm<sup>3</sup> of **FA 6**. The student recorded a value for the reaction time of 70 seconds.
  - Use your graph to calculate the time, to the nearest second, that you would have expected to record if you had carried out an experiment using 7.00 cm<sup>3</sup> of FA 6.
     Show the construction lines on your graph and show your working in the calculation.



(ii) Calculate the percentage difference between your value and that of the student, as a percentage of the student's value.

		M25
percentage difference =	% [1]	

(d) A fifth experiment is to be carried out where the concentrations of potassium iodide, sodium thiosulfate and starch indicator are the same as in **Experiment 2**, but the concentration of iron(III) ions should be twice the value that it is in **Experiment 2**.

State the volume of each solution that should be used for this fifth experiment.

## You do not need to carry out this experiment.

reagent	volume / cm <sup>3</sup>
FA 6	
FA 7	
FA 8	
FA 9	
distilled water	

M26

(e) Thiosulfate ions can also reduce iron(III) ions.

A student carries out the same investigation as in (a) but the solutions are mixed in a different order. The student places **FA 6** and an appropriate volume of distilled water in one beaker and all the other reactants in a second beaker. The student then transfers the mixture from the second beaker to the first and starts timing.

The student proposed that, even though thiosulfate ions are known to reduce iron(III) ions, his method was as good as the method used in **(a)**. Suggest why his assessment is appropriate.



[Total: 16]

#### 3 Determination of the equilibrium constant of a reaction

Aqueous iron(II) ions, Fe<sup>2+</sup>(aq), are usually kept in acidic conditions to prevent them readily oxidising to aqueous iron(III) ions, Fe<sup>3+</sup>(aq).

 $Fe^{2+}(aq)$  ions react with  $Ag^+(aq)$  ions in a redox reaction. The following equilibrium is established.

$$Fe^{2+}(aq) + Ag^{+}(aq) \implies Fe^{3+}(aq) + Ag(s)$$

The concentration of  $Fe^{2+}(aq)$  at equilibrium can be found by titration with a standard solution of aqueous potassium manganate(VII), KMnO<sub>4</sub>(aq).

The equilibrium constant for the reaction can be found using the following equation:

$$K_{c} = \frac{[Fe^{3^{+}}(aq)]_{eqm}}{[Fe^{2^{+}}(aq)]_{eqm} \times [Ag^{+}(aq)]_{eqm}}$$

- (a) An experiment to find the value of the above  $K_c$  can be carried out as follows:
  - Equal volumes of 0.200 mol dm<sup>-3</sup> Ag<sup>+</sup>(aq) solution and 0.200 mol dm<sup>-3</sup> Fe<sup>2+</sup>(aq) solution are mixed in a large conical flask A and shaken.
  - 2. Conical flask **A** is stoppered and left for four hours and shaken intermittently.
  - 3. Conical flask **A** is then left untouched for a further hour to allow any solids to settle.
  - 4. The solution in flask **A** is then carefully decanted into a second conical flask **B**, taking care to leave any solids behind.
  - 5. Solid NaC*l* is carefully added to conical flask **B** to precipitate all the Ag<sup>+</sup> as AgC*l*. The resulting mixture is then filtered.
  - (i) Suggest why conical flask **A** is left for four hours in step 2.



(b) The filtrate obtained from step 5 in (a) contains Fe<sup>2+</sup>(aq) ions. The concentration of the Fe<sup>2+</sup>(aq) ions in the filtrate can be determined by titrating with KMnO<sub>4</sub> in the presence of acid.

**FA 10** is the filtrate from step 5 in **(a)** which contains  $Fe^{2*}(aq)$  ions. **FA 11** is 0.0200 mol dm<sup>-3</sup> potassium manganate(VII), KMnO<sub>4</sub>. **Solution A** is 1 mol dm<sup>-3</sup> sulfuric acid.

In this question, you will carry out the titration to determine the concentration of  $Fe^{2+}(aq)$  in **FA 10.** 

#### (i) Titration of FA 10 against FA 11

- 1. Fill the burette labelled **FA 11** with **FA 11**.
- 2. Use a pipette to transfer 25.0 cm<sup>3</sup> of **FA 10** into a 250 cm<sup>3</sup> conical flask.
- 3. Use the measuring cylinder labelled **A** to add 25.0 cm<sup>3</sup> of **Solution A** into the same conical flask.
- 4. Titrate the mixture in the conical flask until a permanent pale pink colour is obtained.
- 5. Record your titration results, to an appropriate level of precision, in the space provided below.
- 6. Repeat points 2 to 5 until consistent results are obtained.

#### Titration results



(ii) From your titration, obtain a suitable volume of FA 11 to be used in your calculations.
 Show clearly how you obtained this volume.





(c) The ionic equation for the reaction in the titration is shown.

$$MnO_{4}^{-}(aq) + 8H^{+}(aq) + 5Fe^{2+}(aq) \rightarrow 5Fe^{3+}(aq) + 4H_{2}O(I) + Mn^{2+}(aq)$$

Calculate the concentration of  $Fe^{2+}(aq)$  in **FA 10**.



(d) The equilibrium is shown.

$$Fe^{2+}(aq) + Ag^{+}(aq) \implies Fe^{3+}(aq) + Ag(s)$$

(i) Given that the answer you have obtained in (c) is the concentration of  $Fe^{2+}(aq)$  in the equilibrium mixture,  $[Fe^{2+}(aq)]_{eqm}$ , determine the concentration of  $Fe^{3+}(aq)$  in the equilibrium mixture,  $[Fe^{3+}(aq)]_{eqm}$ .



(ii) Suggest why it is **not** necessary to measure  $[Ag^{+}(aq)]_{eqm}$ , the concentration of  $Ag^{+}(aq)$  ions in the equilibrium mixture, experimentally.

[1] M39

(iii) Determine the value of  $K_{c}$ . Include units in your answer.

		M40
		M41
		M42
	$K_{\rm c}$ =	
(e)	In step 5 of the experiment describe in part <b>(a)</b> , addition of a large excess of sodium chloride would result in inaccurate titre values obtained for the titration. Suggest how the titre value would be affected. Explain your answer.	ļ
		M43
	[1]	
(f)	A student proposed that the titration should be carried out using KMnO <sub>4</sub> of a lower concentration in order to obtain a larger titre.	-
	Suggest one reason why a larger titre is better than a smaller titre.	
		M44
	[1]	



## 4 Planning

**FA 12** is a saturated solution of  $Ba(OH)_2$ .

**FA 13** is concentrated HNO<sub>3</sub>.

The reaction between an acid and a metal hydroxide is exothermic, making it possible to determine the equivalence point of a neutralisation reaction through thermometric titration.

By monitoring the temperature change as **FA 12** is gradually added to a fixed volume of **FA 13** solution, distinct temperature patterns emerge. A graph of temperature against volume of **FA 12** added allows for the graphical determination of the equivalence point and the maximum temperature reached through careful extrapolation.

A thermometric titration can therefore be performed to determine the concentration of **FA 12** and the enthalpy change of neutralisation for the following reaction:

 $\frac{1}{2}$  Ba(OH)<sub>2</sub> + HNO<sub>3</sub>  $\rightarrow \frac{1}{2}$  Ba(NO<sub>3</sub>)<sub>2</sub> + H<sub>2</sub>O

(a) To prepare FA 12, a saturated solution of Ba(OH)<sub>2</sub>, an excess amount of solid Ba(OH)<sub>2</sub>.8H<sub>2</sub>O is typically dissolved in a specific volume of water. The resulting solution is then filtered to obtain the saturated solution as the filtrate.

The solubility of Ba(OH)<sub>2</sub> at laboratory conditions is in the range of 0.17 - 0.19 mol dm<sup>-3</sup>.

Determine the maximum mass of Ba(OH)<sub>2</sub>.8H<sub>2</sub>O that can be dissolved in 100 cm<sup>3</sup> of water. [ $A_r$ : Ba, 137.3; O, 16.0; H, 1.0]



(b) Using the mass of Ba(OH)<sub>2</sub>.8H<sub>2</sub>O, that you have determined in (a), you are to plan a thermometric titration experiment of 10 cm<sup>3</sup> of **FA 13** with **FA 12** to determine the enthalpy change of neutralisation,  $\Delta H_n$ , for the reaction between barium hydroxide and nitric acid.

You are provided with:

- 10 g of Ba(OH)<sub>2</sub>.8H<sub>2</sub>O,
- 30 cm<sup>3</sup> of **FA 13**,
- Styrofoam cup,
- digital probe thermometer,
- any other equipment normally found in a school or college laboratory.

Outline how you would carry out the proposed thermometric titration using only the materials provided.

In your plan, you should include:

- the details of how you would prepare 100 cm<sup>3</sup> **FA 12** solution,
- brief, but specific, details of the apparatus you would use, considering the levels of precision they offer,
- the quantities you would use,
- measurements you would make to allow for a graph of temperature against volume of FA 12 added to be drawn, in order to determine the value of ΔH<sub>n</sub> for this reaction, and
- how you would recognise that the equivalence point had been passed.



	•
	•
	•
	•
	•
	•
	•
	•
	•
	•
	M47
	M48
	. M49
	M50
	. M51
	. M52
[6	

(c) From the thermometric titration, a graph of temperature against total volume of **FA 12** added can be plotted.

On the axes below, sketch the graph you would expect to obtain.

You should also indicate on your graph,

- the volume of FA 12 added at equivalence point, V<sub>eq</sub>, and
- the maximum temperature reached, T<sub>max</sub>.



(d) Outline how you would use the measurements in your plan in (b) and your graph to determine the value for  $\Delta H_n$ , the enthalpy change of neutralisation between barium hydroxide and nitric acid.

You may use the following symbols:

 $V_{eq}$  : volume of **FA 12** added at equivalence point (cm<sup>3</sup>)

- T<sub>ini</sub>: initial temperature (°C)
- T<sub>max</sub>: maximum temperature reached (°C)

n<sub>HNO3</sub>: amount of nitric acid (mol)

Assume that 4.18 J is required to raise the temperature of 1 cm<sup>3</sup> of the solution by 1 °C.

[1]

[Total: 11]

# Qualitative Analysis Notes [ppt. = precipitate]

## (a) Reactions of aqueous cations

action	reaction with		
Callon	NaOH(aq)	NH₃(aq)	
aluminium, A <i>l</i> <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess	
ammonium, NH₄⁺ (aq)	ammonia produced on heating	-	
barium, Ba²⁺(aq)	no ppt. (if reagents are pure)	no ppt.	
calcium, Ca <sup>2+</sup> (aq)	white. ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.	
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess	
copper(II), Cu <sup>2+</sup> (aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution	
iron(II), Fe <sup>2+</sup> (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 <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess	
magnesium, Mg <sup>2+</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess	
manganese(II), Mn²⁺(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 <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess	



# (b) Reactions of anions

ion	reaction		
carbonate, CO <sub>3</sub> <sup>2–</sup>	CO <sub>2</sub> liberated by dilute acids		
chloride, C <i>l</i> <sup>–</sup> (aq)	gives white ppt. with Ag <sup>+</sup> (aq) (soluble in $NH_3(aq)$ )		
bromide, Br⁻(aq)	gives pale cream ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq))		
iodide, I⁻(aq)	gives yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq))		
nitrate, NO₃⁻ (aq)	$NH_3$ liberated on heating with $OH^-(aq)$ and $Al$ foil		
nitrite, NO₂ <sup>−</sup> (aq)	NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and A <i>l</i> foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO <sub>2</sub> in air)		
sulfate, SO <sub>4</sub> <sup>2–</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids)		
sulfite, SO <sub>3</sub> <sup>2–</sup> (aq)	SO <sub>2</sub> liberated with dilute acids; gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids)		

## (c) Tests for gases

gas	test and test result		
ammonia, NH <sub>3</sub>	turns damp red litmus paper blue		
carbon dioxide, $CO_2$	gives a white ppt. with limewater (ppt. dissolves with excess CO <sub>2</sub> )		
chlorine, $Cl_2$	bleaches damp litmus paper		
hydrogen, H <sub>2</sub>	"pops" with a lighted splint		
oxygen, O <sub>2</sub>	relights a glowing splint		
sulfur dioxide, SO <sub>2</sub>	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 <sub>2</sub>	reddish brown gas / liquid	orange	orange-red
iodine, $I_2$	black solid / purple gas	brown	purple