

TAMPINES MERIDIAN JUNIOR COLLEGE JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME

CIVICS GROUP

H2 CHEMISTRY

Paper 4 Practical

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 23 and 24.

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

Shift
Laboratory

9729/04

27 August 2024

2 hours 30 minutes

For Examiner's Use		
1	/ 18	
2	/ 15	
3	/ 13	
4	/ 9	
Total	/ 55	

This document consists of 23 printed pages and 1 blank page.

2

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

1 Investigation of some inorganic and organic reactions

In this question, you will be investigating some inorganic and organic reactions by carrying out the stipulated tests. Carefully record your observations in Tables 1.1 and 1.2.

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured.

(a) Organic analysis

In this question, you will deduce the structure of an organic compound, **FA 1**. **FA 1** has the molecular formula $C_4H_8O_2$ with **two** functional groups present.

Do not carry out the tests for which observations have been recorded.

Do not use the Bunsen burner for heating in this part of the question. Instead, use the hot water provided.

	tests	observations
(i)	Place about 2 cm depth of aqueous sulfuric acid in a test-tube. To this test-tube, add about 1 cm depth of FA 1 , followed by 1 drop of aqueous potassium manganate(VII). Warm the mixture in the hot water bath for two minutes.	
(ii)	 Add 1 cm depth of aqueous silver nitrate to a test-tube. Then slowly add 1 cm depth of aqueous sodium hydroxide. Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. To this mixture, add about 1 cm depth of FA 1. Place the test-tube containing the mixture in the water bath for two minutes. 	
(iii)	Place about 1 cm depth of FA 1 in a test-tube. To this test-tube, add 2,4-dinitrophenylhydrazine dropwise.	Orange ppt. formed
(iv)	Place about 1 cm depth of FA 1 and add 8 drops of aqueous sodium hydroxide in a test-tube. Then, add aqueous iodine dropwise, until a permanent yellow / orange colour is obtained.Warm the mixture in the hot water bath for two minutes.	
(v)	Place 1 cm depth of FA 1 in a test-tube. To this test-tube, cautiously add a small piece of anhydrous phosphorus pentachloride.	Dense white fumes, which turns moist blue litmus paper red.

Table 1.1

[2]	
-	

M1	M2	

(b)	(i)	Observations from (a)(ii) and (a)(iii) can be used to identify one of the functional groups present in FA 1 .
		Identify the functional group and explain your answer, showing clearly your reasoning.
		functional group:
		explanation:
		[1]
	(ii)	Using observations from either (a)(iv) or (a)(v) , identify the other functional group present in FA 1 .
		Quote evidence from the relevant test to support your conclusion.
		functional group:
		evidence:
		[1]

(iii) Suggest a possible structure of **FA 1** that are consistent with all the observations in Table 1.1.

[1]

M3	M4	M5	

(c) Inorganic analysis

FA 2 is an aqueous solution containing Fe^{3+} .

FA 3 contains one cation and **FA 4** contains one anion listed in the Qualitative Analysis Notes on pages 23 – 24.

You should indicate clearly at what stage in a test a change occurs. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

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

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitate in an excess of the reagent added

No additional tests for ions present should be attempted.

	tests	observations
(i)	Test the FA 2 solution using Universal Indicator paper.	
(ii)	To 1 cm depth of FA 2 , add 1 cm depth of hydrochloric acid followed by a small spatula of zinc powder. Shake well. Leave the mixture to stand for five minutes.	
(iii)	To 1 cm depth of FA 2 , add a few drops of aqueous sodium thiosulfate with shaking. Leave the mixture to stand.	

Table 1.2

[2]

M6	M7

	tests	observations
(iv)	To 1 cm depth of FA 3 , add an equal volume of aqueous potassium iodide, then	
	add aqueous sodium thiosulfate dropwise with shaking until no further change is observed.	
(v)	To 1 cm depth of FA 3 , add aqueous ammonia slowly, with shaking, until no further change is seen.	

[3]

(d) (i) Explain your observations in (c)(i), given that the cation present in FA 2 is Fe^{3+} .

[4]
 [1]

(ii) State the type of reaction that is likely to have occurred in (c)(iii).

[1]

(iii) Identify the cation present in **FA 3**. Use evidence from your observations in **1(c)** to support your deduction.

cation: evidence: ______[1]

M8	M9	M10	M11	M12	M13

(iv) Write an ionic equation to account for the observations made for the first reaction in (c)(iv). Include state symbols.

[1]

(e) Devise and perform a series of three simple tests to identify the anion in FA 4.

Your tests should be based on the Qualitative Analysis Notes on pages 23 - 24 and should use only the bench reagents provided. Record your tests and observations in the space below.

Any test requiring heating MUST be performed in a boiling tube.

The anion is not a nitrite, sulfate or sulfite ion.

Use your observations above to deduce the identity of the anion in FA 4.

anion:

	[1]

M14	M15	M16	M17	M18

[Total: 18]

2 Determination of the kinetics of the reaction between iron(III) and iodide ions

You are provided with the following reagents.

FA 5 is an acidified solution of aqueous iron(III) chloride, FeCl₃.

FA 6 is aqueous potassium iodide, KI.

FA 7 is 0.0060 mol dm⁻³ sodium thiosulfate, Na₂S₂O₃.

starch solution

In an acidic medium, iron(III) ions, Fe³⁺ oxidises iodide ions, I⁻, to iodine, I₂ as shown in equation 1.

equation 1 $2Fe^{3+}(aq) + 2I^{-}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$

It is possible to determine the rate of this reaction by measuring the time to produce a certain amount of iodine. To do this, a fixed and small amount of thiosulfate ions, S₂O₃²⁻, and starch indicator are added to the reaction mixture. The thiosulfate ions react immediately with the iodine produced by the reaction and convert it back to iodide ions as shown in equation 2.

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

The reaction in equation 2 stops once all the thiosulfate ions have reacted. The concentration of iodine now increases and is detected by starch indicator in the reaction mixture, which causes the reaction mixture to turn blue-black.

You will perform a series of four experiments. Then, you will graphically analyse your results to determine the order with respect to the concentration of Fe³⁺ ions, [Fe³⁺].

For each experiment, you will note the volume of **FA 5** added, V_{FA 5}, and the time taken, *t*, for the reaction mixture to become blue-black. In each experiment, you will need to ensure that the same total volume of reaction mixture is used by adding deionised water as required.

You will then calculate values for

- $\frac{1}{t}$,
- $\lg\left(\frac{1}{t}\right)$,
- $Ig(V_{FA5})$

(a) (i) Experiment 1

- 1. Fill the burette labelled **FA 5** with **FA 5**.
- 2. Transfer 20.00 cm³ of **FA 5** to a 100 cm³ conical flask.
- 3. Use the measuring cylinders to place the following in a 100 cm³ beaker.
 - 10.0 cm³ of **FA 6**
 - 15.0 cm³ of **FA 7**
 - 10.0 cm³ of starch solution
- 4. Add the contents of the beaker rapidly to the conical flask and start the stopwatch.
- 5. Swirl the mixture and place the conical flask on the white tile.
- 6. Stop the stopwatch when the **blue-black colour first appears**. Ignore any colour changes that occur before the intense blue-black colouration.
- 7. Record the time taken, *t*, to nearest second in your table.
- 8. Discard the reaction mixture **immediately** down the sink. Wash out the conical flask and stand it upside down on a paper towel to drain.

(ii) Experiment 2

- 1. Run 8.00 cm³ of **FA 5** into a 100 cm³ conical flask.
- 2. Using another measuring cylinder, add 12.0 cm³ of deionised water into the conical flask containing **FA 5**.
- 3. Use the measuring cylinders to place the following in a 100 cm³ beaker.
 - 10.0 cm³ of **FA 6**
 - 15.0 cm³ of **FA 7**
 - 10.0 cm³ of starch solution
- 4. Add the contents of the beaker rapidly to the conical flask and start the stopwatch.
- 5. Swirl the mixture and place the conical flask on the white tile.
- 6. Stop the stopwatch when the **blue-black colour first appears**. Ignore any colour changes that occur before the intense blue-black colouration.
- 7. Record the time taken, *t*, to nearest second in your table.
- 8. Discard the reaction mixture **immediately** down the sink. Wash out the conical flask and stand it upside down on a paper towel to drain.

In Experiment 1 you will have obtained the time taken for a 'fast' reaction and in Experiment 2 the time taken for a 'slow' reaction.

Carry out **two** further experiments to investigate the effect of changing the concentration of $Fe^{3+}(aq)$ by altering the volume of **FA 5** used. In each case, you will need to ensure that the **same total volume** of reaction mixture is used by adding deionised water as required.

Do not use a volume of **FA 5** that is less than 8.00 cm^3 .

You should alternate the use of the two 100 cm³ conical flasks.

Record all required volumes, time taken and calculated values in your table.

(iii) Results

The volumes of FA 6, FA 7 and starch indicator are not changed in these experiments, and do not need to be recorded.

Prepare a table in the space provided below to record, to an appropriate level of precision:

- volumes of FA 5 and deionised water, .
- all values of t, •

• all calculated values of
$$\frac{1}{t}$$
, $Ig\left(\frac{1}{t}\right)$ and $Ig(V_{FA 5})$.

.

	[4]
M21	M22

M19

M20

(b) (i) Plot a graph of $Ig\left(\frac{1}{t}\right)$ on the y-axis against Ig (V_{FA 5}) on the x-axis. Draw the best-fit straight line taking into account all of your plotted points



[3]

(ii) Calculate the gradient of the line to three significant figures, showing clearly how you did this. Hence, state the order of reaction with respect to [Fe³⁺].

gradient =	
order =	 [2]

M23	M24	M25	M26	M27

(c) (i) Calculate the amount of thiosulfate ions, $S_2O_3^{2-}$, used in each experiment in 2(a).

amount of
$$S_2O_3^{2-} =$$
 [1]

(ii) Use your answer to (c)(i), and the equations for the reactions involved, to calculate the amount of iron(III) ions, Fe³⁺, that reacted when the blue-black colour first appear in each experiment in **2(a)**.

amount of Fe^{3+} = [1]

(iii) Hence, calculate the change in concentration of Fe³⁺ that occurred when the blue-black colour first appear in each experiment in **2(a)**.

change in [Fe³⁺] = [1]

M28	M29	M30

(iv) The $\frac{1}{t}$ calculated in the results table in (a)(iii) is a relative rate. The experimental rate of this reaction can be monitored by the change in concentration of Fe³⁺ per unit time as given in the expression below.

experimental rate =
$$-\frac{\text{change in } \left[\text{Fe}^{3+}\right]}{\text{time, } t} \times 10^6 \text{ } \mu\text{mol } \text{dm}^{-3} \text{ s}^{-1}$$

 $(1 \ \mu mol = 10^{-6} \ mol)$

Calculate the experimental rate of reaction for **Experiment 1**, taking into consideration the required units.

experimental rate of reaction for experiment 1 = $\mu mol dm^{-3} s^{-1}$ [1]

(d) The order of reaction with respect to [I-] is one.

With reference to **Experiment 1**, state and explain the expected time taken for the appearance of the dark blue-black colour when the experiment is carried out using a mixture comprising the following:

- 20.00 cm³ of **FA 5**
- 5.0 cm³ of **FA 6**
- 7.5 cm³ of **FA 7**
- 12.5 cm³ of deionised water
- 10.0 cm³ of starch

[1]

M31	M32

(e) Step 8 of Experiment 1 in 2(a) instructs you to wash and drain the conical flask before it is used again.

State and explain the likely effect on time taken, *t*, if a student had washed the conical flask but had failed to drain it before starting another experiment.

effect on t		
explanation		
		•••
	[1]

M33	

[Total: 15]



3 To determine the composition of a mixture of sodium carbonate and sodium hydrogen carbonate

FA 8 contains 3.90 g dm⁻³ of a mixture of sodium carbonate, Na₂CO₃ and sodium hydrogen carbonate, NaHCO₃.

FA 9 is 0.0700 mol dm⁻³ hydrochloric acid, HC*l*.

Solution **M** is methyl orange indicator.

Sodium carbonate in aqueous solution acts as a *Brønsted-Lowry* base. It reacts with acid in two stages.

In the first stage, it accepts a proton to form sodium chloride and sodium hydrogen carbonate. In the second stage, sodium hydrogen carbonate combines with another proton to form sodium chloride, carbon dioxide and water.

Stage 1 $Na_2CO_3(aq) + HCl(aq) \rightarrow NaCl(aq) + NaHCO_3(aq)$

Stage 2 NaHCO₃(aq) + HCl(aq) \rightarrow NaCl(aq) + CO₂(g) + H₂O(l)

The end-point for Stage 1 occurs at pH 8.3 and is determined using thymol blue indicator.

The end-point for Stage 2 occurs around pH 3.7 and is determined using methyl orange indicator.

In this experiment, you are required to determine the end-point for Stage 2 for this reaction and determine the concentrations of sodium carbonate, and that of sodium hydrogen carbonate, in **FA 8**.

(a) Titration of FA 8 against FA 9, using methyl orange as the indicator

- 1. Fill the burette with **FA 9**.
- 2. Use a pipette to transfer 25.0 cm³ of **FA 8** into a 250 cm³ conical flask.
- 3. Add a few drops of solution **M** to the conical flask.
- 4. Run **FA 9** from the burette into this conical flask. The end-point is reached when the solution changes from yellow to orange. If the solution becomes red, you have passed the end-point.
- 5. Record your titration results in Table 3.1 on page 15.
- 6. Repeat steps 1 to 5 until consistent results are obtained.

Results

Table 3.1

Titration		
Initial burette reading / cm ³		
Final burette reading (second end-point) / cm ³		
Volume of FA 9 used to complete both Stages 1 and 2, V_t / cm ³		

(b) Using your titration results, obtain a suitable volume of **FA 9** for the second end-point (total volume of **FA 9** used to complete both stages 1 and 2).

Show clearly how you obtained this volume.

volume of **FA 9** used for second end-point = cm^3

[3]

[2]

M34	M35	M36	M37	M38

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(c) (i) For the titration of **FA 8** against **FA 9** using thymol blue as the indicator, the titre value for the first end-point, V_1 (volume of **FA 9** used to complete stage 1) is determined to be 9.15 cm³.

Calculate the amount, in moles, of sodium carbonate, Na_2CO_3 , and sodium hydrogen carbonate, $NaHCO_3$, present in 25.0 cm³ of **FA 8**.

amount of Na₂CO₃ in 25.0 cm³ of **FA 8** = ______ amount of NaHCO₃ in 25.0 cm³ of **FA 8** = ______[2]

(ii) Calculate the concentrations, in mol dm^{-3} , of Na₂CO₃ and NaHCO₃ in **FA 8**.

concentration of Na_2CO_3 in FA 8 =	
concentration of NaHCO ₃ in FA 8 =	[3]

M39	M40	M41	M42	M43

(d) Explain why methyl orange can be used as the indicator for Stage 2 of this titration.

[1]

(e) A student used 25.0 cm³ of **FA 8** and obtained a **FA 9** titre value of 25.15 cm³ for the second end point. The errors (uncertainties) associated with each apparatus is given below.

pipette	± 0.06 cm ³	
burette	± 0.05 cm ³	

Calculate the percentage error arising from the use of the following apparatus.

• 25.0 cm³ pipette

% error (pipette)

• burette

% error (burette) [1]

(f) A student performed the titration using $CH_3CO_2H(aq)$ instead of HCl(aq). State and explain the effect on the volume of acid required for the first end-point.

[1]

M44	M45	M46

[Total: 13]

4 Planning

The reaction between aqueous sodium chloride, NaCl and aqueous lead(II) nitrate, $Pb(NO_3)_2$ produces an insoluble white precipitate of $PbCl_2$.

 $Pb(NO_3)_2(aq) + 2 NaCl(aq) \rightarrow PbCl_2(s) + 2 NaNO_3(aq)$

The concentration of an aqueous solution of lead(II) nitrate can be determined gravimetrically by monitoring the mass of precipitate formed as different volumes of aqueous sodium chloride and aqueous lead(II) nitrate are mixed. A graph of mass of precipitate against volume of aqueous sodium chloride added allows for the graphical determination of the equivalence point through careful extrapolation. At this equivalence point, stoichiometric quantities of reactants are present.

Plan an experiment to determine the concentration of an aqueous solution of lead(II) nitrate gravimetrically.

You may assume that you are provided with:

- solid sodium chloride, NaCl
- 250 cm³ of approximately 0.1 mol dm⁻³ aqueous solution of lead(II) nitrate
- the equipment normally found in a school or college laboratory
- (a) Describe how you would make 250 cm³ of a solution of sodium chloride of concentration 0.200 mol dm⁻³ for your experiment.
 [A_r: Na, 23.0; C*l*, 35.5]

M47	M48	

(b) In order to determine the concentration of the solution of lead(II) nitrate, sufficient data must be collected to plot a graph of mass of precipitate formed against the volume of sodium chloride used.

In your plan, you should only use the solution of sodium chloride you planned to make in (a) and the aqueous solution of lead(II) nitrate provided. No additional chemicals are provided.

The choice for the individual volumes of aqueous sodium chloride and aqueous lead(II) nitrate should be chosen in a way such that mixing the two together gives a reaction mixture of the same total volume for each experiment.

Your plan should include brief details of:

- the apparatus you would use,
- the quantities of reagents you would use in each experiment,
- the procedure you would follow to obtain dry and pure precipitate,
- the measurements you would take to allow for the graph to be drawn,
- how you would ensure that the results obtained are accurate and reliable.

[5]

.....

M49	M50	M51	M52	M53

(c) (i) Sketch the graph that you would expect to obtain on the axes provided in Fig. 4.1. [1]



Fig. 4.1

(ii) Describe how you would use your graph to determine the concentration of the lead(II) nitrate solution. [1]

M54	M55

[Total: 9]

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Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	reaction with			
cation	NaOH(aq)	NH₃(aq)		
aluminium,	white ppt.	white ppt.		
A <i>l</i> 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, 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),	red-brown ppt.	red-brown ppt.		
Fe ³⁺ (aq)	insoluble in excess	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, Zn²+(aq)	white ppt. soluble in excess	white ppt. soluble in excess		

(b) Reactions of anions

anion	reaction
carbonate, CO3 ²⁻	CO ₂ liberated by dilute acids
chloride, C <i>t</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 (pale) \rightarrow brown NO_2 in air)
sulfate, SO4 ^{2–} (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acid)
sulfite, SO ₃ ² ⁻ (aq)	SO ₂ liberated with dilute acids; gives white ppt. with Ba ²⁺ (aq) (soluble in dilute strong acid)

(c) Test for gases

gas	tests 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