TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	

H2 CHEMISTRY **9729/04**

Paper 4 Practical **4 September 2019**

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 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 scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Qualitative Analysis Notes are printed on pages 17 and 18.

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	
2	
3	
Total	

This document consists of **18** printed pages.

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

1 Determination of the concentration of a base and the enthalpy change of the neutralisation reaction

FA 1 is 2.0 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 2 is aqueous sodium hydroxide, NaOH.

The reaction of sulfuric acid and sodium hydroxide is exothermic.
In separate experiments, you will add increasing volumes of **FA 2** to a fixed volume of **FA 1**. In each experiment you will measure the maximum temperature rise, ΔT. As the volume of **FA 2** is increased, this maximum temperature rise, ΔT, will increase and then decrease.

By measuring the maximum temperature rise for different mixtures of the two reagents, you are to determine the following:

- the concentration of sodium hydroxide, NaOH, in **FA 2**
- the enthalpy change when 1 mol of H_2SO_4 is neutralised by NaOH

(a) Method

- Fill the labelled burette with **FA 1**.
- Support a styrofoam cup in the 250 cm^3 beaker.
- Run 10.00 cm^3 of **FA 1** from the burette into the styrofoam cup.
- Measure 20.0 cm^3 of **FA 2** using a measuring cylinder.
- Place the thermometer in the **FA 2** in the measuring cylinder and record the steady temperature of the solution.
- Pour the **FA 2** into the styrofoam cup, stir and record the maximum temperature obtained in the reaction.
- Empty and rinse the styrofoam cup; shake dry the styrofoam cup. Rinse the thermometer.
- Carry out the experiment three more times. Each time use 10.00 cm^3 of **FA 1**.
- Use 30.0 cm^3, 40.0 cm^3 and 50.0 cm^3 of **FA 2** in these different experiments.

Carry out **two further experiments**.
Choose volumes of **FA 2** which will allow you to investigate more precisely the volume of **FA 2** that produces the highest temperature rise when added to 10.00 cm^3 of **FA 1**.

Results
Record your results below in an appropriate form showing, for each experiment, the volumes of solutions used, temperature measurements and the temperature rise, ΔT.

[4]

(b) Plot a graph of temperature rise, ΔT, on the y-axis against the volume of **FA 2** added on the x-axis.

Draw a line of best fit through the points where the temperature rise is increasing and another line through the points where the temperature rise is decreasing.

The intersection of these lines represents the temperature rise for the volume of **FA 2** that exactly neutralises the sulfuric acid present in 10.00 cm^3 of **FA 1**.

[3]

(c) Read from the graph the volume of **FA 2** that gives the maximum temperature rise.

Volume of **FA 2** giving the maximum temperature rise = ... cm^3 [1]

(d) **(i)** Calculate the amount of NaOH required to neutralise the amount of H_2SO_4 at the maximum temperature rise.

Amount of NaOH required = ... mol
[1]

(ii) Hence, calculate the concentration of NaOH in **FA 2**.

Concentration of NaOH in **FA 2** = ... mol dm^{-3}
[1]

(e) Read the maximum temperature rise from the graph and use this to calculate the enthalpy change when 1 mol of H_2SO_4 is neutralised by NaOH. Give your answer in kJ mol^{-1}.

[4.18 J are absorbed or released when the temperature of 1 cm^3 of solution changes by 1 °C.]

Enthalpy change = ... kJ mol^{-1}
[2]

(f) The enthalpy change of neutralisation, ΔH_{neut}, between a strong acid and a strong base is -57 kJ mol^{-1}.

Explain why the enthalpy change calculated in **(e)** is significantly more exothermic than ΔH_{neut}.

....

....

....[1]

(g) A student suggested that the experiments carried out in **(a)** would be more accurate if volumes of 20.00 cm^3 of 1.0 mol dm^{-3} H_2SO_4 were used instead.

State and explain whether you agree or disagree with the student's suggestion.

evaluation of student's suggestion ....

explanation ....

....
[1]

[Total: 14]

2 Determination of the percentage by mass of sodium carbonate in a mixture of sodium hydroxide and sodium carbonate

Sodium carbonate is neutralised by hydrochloric acid in two steps:

$Na_2CO_3 + HCl \rightarrow NaCl + NaHCO_3$
$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

This step-wise neutralisation can be observed when the acid is added slowly to the sodium carbonate.

The percentage by mass of sodium carbonate in a mixture of sodium hydroxide and sodium carbonate can be determined by carrying out titrations using two different indicators. Since both sodium hydroxide and sodium carbonate react with acids, through careful selection of the indicators used for the titration, the volume of acid required to react with only the sodium carbonate can be found.

FA 3 is 0.125 mol dm^{-3} hydrochloric acid, HCl.
FA 4 is an aqueous solution containing sodium hydroxide, NaOH, and sodium carbonate, Na_2CO_3.

You are also provided with bromophenol blue indicator.

In this question, you will carry out titrations to determine the percentage by mass of sodium carbonate in the mixture of sodium hydroxide and sodium carbonate in solution **FA 4**.

(a) (i) Titration of FA 4 against FA 3 using bromophenol blue

1. Fill a burette with **FA 3**.
2. Pipette 25.0 cm^3 of **FA 4** into a conical flask.
3. Add four to five drops of bromophenol blue indicator.
4. Titrate the mixture in the flask with **FA 3** until the blue-violet colour of the solution changes to yellow.
5. Record your titration results, to an appropriate level of precision, in the space provided.

Repeat steps 2 to 5 to obtain consistent results.

Titration results

[6]

(ii) From your titration results, obtain a suitable volume of **FA 3**, $V_{\mathbf{FA\ 3}}$, to be used in your calculations. Show clearly how you obtained this volume.

$V_{\mathbf{FA\ 3}}$ = ...

[1]

(b) When the titrations in **(a)** were repeated using **phenolphthalein** as the indicator, 25.0 cm^3 of **FA 4** required 15.00 cm^3 of **FA 3**.

The following explains why different results are obtained using two different indicators.

- When phenolphthalein is used as the indicator, the following reactions have taken place at the end-point of the titration.

Reaction 1 $NaOH + HCl \rightarrow NaCl + H_2O$

Reaction 2 $Na_2CO_3 + HCl \rightarrow NaCl + NaHCO_3$

- When bromophenol blue is used as the indicator in **(a)**, the following reactions have taken place at the end-point of the titration.

Reaction 1 $NaOH + HCl \rightarrow NaCl + H_2O$

Reaction 2 $Na_2CO_3 + HCl \rightarrow NaCl + NaHCO_3$

Reaction 3 $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

For the titration using **bromophenol blue**, the amount of Na_2CO_3 reacted in *Reaction 2* is equal to the amount of sodium bicarbonate, $NaHCO_3$, reacted in *Reaction 3*. Both the amounts of Na_2CO_3 reacted in *Reaction 2* using **phenolphthalein or bromophenol blue** are the **same**.

Show your working and use appropriate significant figures in the final answers to all steps of your calculations.

(i) Calculate the amount of HC*l* in the volume of **FA 3**, $V_{\textbf{FA 3}}$, determined in **(a)(ii)**.

Amount of HC*l* in $V_{\textbf{FA 3}}$ = ...

(ii) Calculate the amount of HC*l*, in 15.00 cm^3 of **FA 3**.

Amount of HC*l* in 15.00 cm^3 of **FA 3** = ...

[1]

(iii) With reference to the information given in **(b)** and your answers to **(b)(i)** and **(b)(ii)**, calculate the amount of HC*l* that reacted with Na_2CO_3 in *Reaction 2* using **phenolphthalein** indicator.

Amount of HC*l* reacted with Na_2CO_3 in *Reaction 2* using phenolphthalein = ...

[1]

(iv) Use your answer to **(b)(iii)** to calculate the mass of Na_2CO_3 present in 25.0 cm^3 of **FA 4**.
[A_r : C, 12.0; O, 16.0; Na, 23.0]

Mass of Na_2CO_3 in 25.0 cm^3 of **FA 4** = ...

[1]

(v) The **overall** equation for the reaction of Na_2CO_3 with HC*l* when **bromophenol blue** is used as indicator is given below.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$$

Calculate the amount of HC*l* that reacted with Na_2CO_3 in the above equation in 25.0 cm^3 of **FA 4**.

Amount of HC*l* reacted with Na_2CO_3 using bromophenol blue = ...

[1]

(vi) Use your answers to **(b)(i)** and **(b)(v)** to calculate the mass of NaOH in 25.0 cm^3 of **FA 4**.
[A_r : H, 1.0; O, 16.0; Na, 23.0]

Mass of NaOH in 25.0 cm^3 of **FA 4** = ...

[1]

(vii) Calculate the percentage by mass of Na_2CO_3 in the mixture of NaOH and Na_2CO_3 in **FA 4**.

FA 4 contains .... % by mass of Na_2CO_3

[2]

(c) The error (uncertainty) associated with **each reading** is given as follows:

50.00 cm^3 burette:	±0.05 cm^3
25.0 cm^3 pipette:	±0.06 cm^3

Calculate the percentage error (uncertainty) when a
- 50.00 cm^3 burette
- 25.0 cm^3 pipette

is used to measure 25 cm^3 of **FA 4** into the conical flask.

Hence explain whether the 50.00 cm^3 burette or the 25.0 cm^3 pipette will be a more precise apparatus to measure 25 cm^3 of **FA 4**.

percentage error (uncertainty) of burette = ... %

of pipette = ... %

explanation ....

....

[2]

(d) Planning

You are to plan an experiment to determine the percentage by mass of sodium carbonate in an unknown solid sample by measuring the volume of carbon dioxide gas evolved on reaction with excess acid at room temperature and pressure.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$$

You may assume that you are provided with:
- 0.5 mol dm^{-3} hydrochloric acid, HC*l*;
- 0.5 g impure solid sample containing sodium carbonate, Na_2CO_3. Other impurities present are assumed to have no reaction with acid;
- 100 cm^3 gas syringe for gas collection;
- apparatus normally found in a school laboratory.

Your plan should include:
- calculations of suitable mass of impure sample and volume of excess hydrochloric acid to be used, based on a 100 cm^3 gas syringe;
- a fully-labelled diagram of the experimental set-up;
- practical details of how you would
  - ensure a known mass of solid sample and volume of acid are measured;
  - determine the volume of carbon dioxide evolved, including the measurements to be made;
  - ensure that an **accurate** and **reliable** volume of gas is obtained.

  [M_r : Na_2CO_3, 106.0]

Diagram

....

....

....

....

....

....

....

[7]

[Total: 23]

3 Qualitative Analysis

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

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

You should indicate clearly at what stage in a test a change occurs.
If there is no observable change, write **no observable change**.

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

(a) **FA 5** contains **two** cations and **two** anions from the lists on pages 17 and 18.

- To approximately half a boiling tube of distilled water, add all the **FA 5**.
- Stopper and shake the boiling tube thoroughly for one minute to make sure that no more of the solid will dissolve.
- Filter the mixture into a clean boiling tube.
- Place the filter funnel in a conical flask and wash the residue well with distilled water.
- **Keep both filtrate and residue for (a)(i) and (a)(ii) respectively.**

While you are waiting for the mixture to filter, continue with (b) or (c).

(i) Tests on the filtrate

Carry out the following tests and record your observations in Table 3.1 below.

Table 3.1

	test	observations
1.	To a 1 cm depth of the filtrate in a test-tube, add aqueous ammonia, slowly with shaking until no further change is seen;	[1]
	then add aqueous hydrogen peroxide.	[1]

(ii) Tests on the residue

Carry out the following tests and record your observations in Table 3.2 below.

Table 3.2

	test	observations
2.	Place the funnel containing the residue into a clean test-tube. Pour approximately 5 cm^3 of dilute nitric acid onto the residue. Collect the resultant filtrate. Discard the first 1 cm depth of this resultant filtrate and collect the remaining filtrate in another clean test-tube for test 3.	[1]
3.	To 1 cm depth of the solution in a test-tube, add aqueous sodium hydroxide, slowly with shaking until no further change is seen.	[1]

(iii) Identify the **two** cations present in **FA 5**. Use evidence from your observations in **(a)(i)** and **(a)(ii)** to support your deduction.

cations present .... and ....

evidence ....

....

....

.... [2]

(iv) The tests you have carried out in **(i)** and **(ii)** would have enabled you to identify only one of the two anions present in **FA 5**. Identify this anion.

anion present .... [1]

(v) Suggest what type of reaction is happening when hydrogen peroxide is added in test **(a)(i)**.

.... [1]

(vi) In test 1 of **(a)(i)**, aqueous ammonia behaved as an Arrhenius base:

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

In a separate experiment, an equal volume of aqueous ammonium chloride, NH_4Cl was added to a second portion of the filtrate that was used in **(a)(i)**. When aqueous ammonia was then added to this resultant solution, no precipitate formed.

Suggest an explanation for the results of this experiment.

....

....

....

....[2]

(b) **FA 6** is an aqueous solution containing nickel(II) ion.

Carry out the following tests on **FA 6** and record your observations in Table 3.3 below.

Table 3.3

	test	*observations*
(i)	To a 1 cm depth of **FA 6** in a test-tube, add aqueous ammonia, slowly with shaking, until no further change is seen.	[1]
(ii)	To a 1 cm depth of **FA 6** in a test-tube, add aqueous sodium hydroxide, slowly with shaking, until no further change is seen.	[1]

(iii) Nickel(II) ions form complexes with ligands such as ammonia and ethylenediamine as shown:

$[Ni(H_2O)_6]^{2+}(aq) + 6NH_3(aq) \rightleftharpoons [Ni(NH_3)_6]^{2+}(aq) + 6H_2O(l)$ $K_c = 4.8 \times 10^7\ mol^{-6}\ dm^{18}$

$[Ni(H_2O)_6]^{2+}(aq) + 3en(aq) \rightleftharpoons \underset{\text{purple}}{[Ni(en)_3]^{2+}(aq)} + 6H_2O(l)$ $K_c = 2.0 \times 10^{18}\ mol^{-3}\ dm^9$

[en ≡ ethylenediamine]

The observation in **(b)(i)** is due to the formation of the nickel-ammonia complex.

Suggest, with reason, what might be observed if aqueous ammonia were added to a solution containing $[Ni(en)_3]^{2+}$ ions instead of $Ni^{2+}(aq)$.

....

....

....

....[2]

(c) **FA 7**, **FA 8** and **FA 9** are 1.0 mol dm^{-3} sulfuric acid, 0.1 mol dm^{-3} sulfuric acid and 1.0 mol dm^{-3} hydrochloric acid, but not necessarily in that order.

You are to plan and carry out **two** simple tests, using only the bench reagents provided, which will enable you to determine the identities of **FA 7**, **FA 8** and **FA 9**.

You should record, in a suitable form in the space below, your tests and observations. You should show clearly the observations for each of **FA 7**, **FA 8** and **FA 9** with all test reagents.

FA 7 is ....

FA 8 is ....

FA 9 is ....

[4]

[Total: 18]

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 A*l* foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and A*l* foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-}(aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acids)

(c) Test 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