CANDIDATE NAME	( )	CLASS	18S0		

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RAFFLES INSTITUTION
2018 YEAR 6 PRELIMINARY EXAMINATION

Higher 2

CHEMISTRY 9729/04

Paper 4 Practical

29 August 2018

2 hours 30 minutes

Do NOT turn over the Question Booklet until you are told to do so.

READ THESE INSTRUCTIONS FIRST

Write your name and class on the space provided when instructed to do so.
Give details of the practical shift and laboratory, where appropriate, in the space 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	
Bench Number	

For Examiner's Use	
Question	**Marks**
1	**/ 14**
2	**/ 25**
3	**/ 16**
Total	**/ 55**

This document consists of **17** printed pages and **1** blank page.

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

1 Determination of the concentration of $CuSO_4$ in FA 2

You are provided with the following solutions:

FA 1 0.0500 mol dm^{-3} aqueous sodium thiosulfate, $Na_2S_2O_3$
FA 2 aqueous $CuSO_4$ solution of unknown concentration
FA 3 100 g dm^{-3} solution of sodium iodide, NaI
Starch solution

Copper(II) ions react with iodide ions according to the following equation.

$$2Cu^{2+}(aq) + 4I^{-}(aq) \longrightarrow 2CuI(s) + I_2(aq)$$

The iodine produced in this reaction may be titrated against **FA 1** using starch solution as indicator. Thiosulfate ions react with iodine according to the following equation:

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

Estimating the required dilution factor for FA 2

(a) The solution of **FA 2** provided is too concentrated to be used directly for reaction with **FA 3** to produce iodine for titration against **FA 1**.

A preliminary experiment was carried out to estimate a dilution factor for the **FA 2** solution, so that 25 cm^3 of this diluted solution would require approximately 25 cm^3 of **FA 1** for complete reaction. It was found that 30 drops of **FA 1** were needed to react completely with the iodine produced from the reaction between 5 drops of **FA 2** and excess **FA 3**.

Use the information above to calculate the volume of **FA 2** needed to make 250 cm^3 of the diluted $CuSO_4$ solution, **FA 4**.

[1]

Preparation of FA 4 by dilution of FA 2

(b) You will now follow the instructions given below to prepare **FA 4**, a diluted solution of **FA 2**.

1. Using a burette, measure between 40.00 and 42.00 cm^3 of **FA 2** into a 250 cm^3 graduated flask.

2. Record in the space below, your burette readings and the volume of **FA 2** transferred to the flask.

[2]

3. Fill the graduated flask to the 250 cm^3 mark with deionised water, stopper and mix thoroughly by inverting the flask a number of times.

   The diluted $CuSO_4$ solution you have prepared is **FA 4**.

Titration

1. Fill the second burette with **FA 1**.
2. Pipette 25.0 cm^3 of **FA 4** into a conical flask.
3. Use the measuring cylinder provided to add 10 cm^3 of **FA 3** to the conical flask.

   *As described earlier, the Cu^{2+} ions in **FA 4** react with I^- ions from **FA 3** to produce I_2, which can be titrated with **FA 1**. The reaction also produces a cream precipitate of CuI.*
4. Titrate the iodine in the conical flask with **FA 1** until the brown colour of the iodine becomes pale brown.
5. Add about 10 drops of starch solution to the flask and continue adding **FA 1** until the blue-black colour just disappears.
6. Repeat the titration as many times as you think necessary to obtain consistent results. Record your titration results in the space below.

Results

[5]

(c) Indicate clearly which results you have used, and show with calculation the volume of **FA 1** used.

……….....… cm^3 of **FA 4** produced an amount of iodine which required ……….....… cm^3 of **FA 1** for complete reaction.

[1]

(d) Calculate the number of moles of $S_2O_3^{2-}$ in the volume of **FA 1** recorded in **(c)**, and hence determine the molar concentration of Cu^{2+} ions in **FA 4**.

number of moles of $S_2O_3^{2-}$ = ……………………..……

concentration of Cu^{2+} in **FA 4** = ………………………………

[2]

(e) Using the volume of **FA 2** recorded in **(b)**, calculate the molar concentration of $CuSO_4$ in **FA 2**.

concentration of $CuSO_4$ in **FA 2** = ……………………………….[1]

(f) A student repeated the experiment using 50 g dm^{-3} sodium iodide solution instead. Predict, using calculations, if the titre volumes obtained would differ when the new solution of iodide ions is used.
(A_r: Na = 23.0; I = 126.9)

[2]

[Total: 14]

2 Determination of the concentration of NaC*l*O and a value for an enthalpy change of reaction, ΔH_{rxn}

You are provided with the following solutions:

FA 5 is an aqueous solution containing sodium chlorate(I), NaC*l*O.
FA 6 is an aqueous solution of 0.100 mol dm^{-3} sodium thiosulfate in aqueous sodium hydroxide.

You are to perform a series of experiments using different volumes of **FA 5** and **FA 6** which together give a total volume of **40.0 cm^3**. The temperature change, ΔT, for each experiment will be determined and you will plot a graph of ΔT against the volume of **FA 5** used.

You will then use data from your graph to determine the concentration of sodium chlorate(I) in **FA 5**. You will also use data from your graph to determine a value for the enthalpy change of reaction, ΔH_1, for the reaction between aqueous sodium chlorate(I) and sodium thiosulfate.

$$4NaClO(aq) + Na_2S_2O_3(aq) + 2NaOH(aq) \xrightarrow{\Delta H_1} 4NaCl(aq) + 2Na_2SO_4(aq) + H_2O(l) \text{ --- Reaction } \mathbf{1}$$

(a) Procedure

Follow the steps below to determine the temperature changes when different volumes of **FA 5** and **FA 6** are reacted together.

1. Use a 50 cm^3 measuring cylinder to transfer 10.0 cm^3 of **FA 5** into a Styrofoam cup. Place this cup containing **FA 5** inside a second Styrofoam cup which is placed in a 250 cm^3 glass beaker to prevent it from tipping over.

2. Place a thermometer into the cup containing **FA 5**. Stir gently, measure and record the temperature of the **FA 5** solution, T_1.

3. Using another 50 cm^3 measuring cylinder, transfer 30.0 cm^3 of **FA 6** into the cup containing **FA 5**. Use the thermometer to stir the mixture gently. Measure and record the highest temperature, T_2, of the mixture.

4. Empty, wash and carefully dry the Styroform cup.

5. Repeat steps 1 to 4 using 20.0 cm^3, 30.0 cm^3 and 35.0 cm^3 of **FA 5**, each time using the appropriate volume of **FA 6** so that the total volume of the mixture is 40.0 cm^3.

6. Record all measurements of volume, temperature and temperature change, ΔT, in an appropriate format in the spaces provided on the next page. The data for these four experiments should be recorded together with the two or three additional experiments described in **(b)(ii)**.

(b) (i) Results

[4]

(ii) Plot the points of temperature change, ΔT, against volume of **FA 5** using the four experimental results that you have obtained.

By considering your plotted points, perform two or three additional experiments to identify the volume of **FA 5** needed to produce the maximum temperature change, ΔT_{max}. In each experiment, ensure that the total volume of the reaction mixture is 40.0 cm^3. You may find it helpful to plot the results from each experiment before choosing the volumes to use in the next experiment. [4]

(iii) Draw two lines of best fit for the points plotted and extrapolate both lines to find the maximum temperature change, ΔT_{max}, and the volume of **FA 5** required to completely react with the amount of **FA 6** used, V_{rxn}.

Record these values in the spaces provided below.

From the graph,

maximum temperature change of reaction mixture, ΔT_{max} = …………………

volume of **FA 5** required for complete reaction, V_{rxn} = ………………… [2]

(c) Use your results from part **(b)(iii)** to calculate:

(i) the concentration, in mol dm^{-3}, of sodium chlorate(I), NaC*l*O, in **FA 5**.

concentration of NaC*l*O in **FA 5** = ………………………………….[2]

(ii) the enthalpy change of reaction, ΔH_1, in kJ mol^{-1}, for the reaction between **FA 5** and **FA 6** in reaction **1**.

You should assume that the specific heat capacity of the final solution is 4.18 J g^{-1} K^{-1} and that its density is 1.00 g cm^{-3}.

ΔH_1 = ………………………………….[2]

(d) Predict and explain if ΔT_{max} will be affected when the volumes of **FA 5** and **FA 6** used in the reaction are doubled.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………[1]

(e) Planning

FA 6 is an aqueous solution of 0.100 mol dm^{-3} sodium thiosulfate in aqueous NaOH.

FA 7 is an impure sample of solid sodium chlorate(I), NaC*l*O, with a percentage purity of about 80%.

The percentage purity of NaC*l*O in **FA 7** and the enthalpy change of reaction, ΔH_2, of the following reaction is to be determined.

$$4NaClO(s) + Na_2S_2O_3(aq) + 2NaOH(aq) \xrightarrow{\Delta H_2} 4NaCl(aq) + 2Na_2SO_4(aq) + H_2O(l) \text{ -- Reaction } \mathbf{2}$$

This can be done by performing experiments to find the maximum temperature rise when known masses of **FA 7** are **separately** added to 30 cm^3 of **FA 6** and plotting the graph of maximum temperature rise against mass of **FA 7** used.

You may assume that the impurity present in **FA 7** does not react with **FA 6** and does not cause a change in temperature when dissolved in water.

(i) Calculate the mass of NaC*l*O required to react completely with 30 cm^3 of **FA 6**.
(A_r: Na = 23.0; C*l* = 35.5; O = 16.0)

[1]

(ii) Hence, calculate the mass of **FA 7** required to react completely with 30 cm^3 of **FA 6**, assuming that the percentage purity of NaC*l*O in **FA 7** is 80%.

[1]

(iii) Plan an investigation, based on the description outlined above, to determine the percentage purity of NaC*l*O in **FA 7** and the enthalpy change of reaction, ΔH_2, of reaction **2**.

You may assume that you are provided with

- **FA 6** and **FA 7**,
- an analytical balance,
- a weighing bottle,
- the equipment normally found in a school or college laboratory.

Your plan should include the following:

- an outline of how the mass of **FA 7** used is determined,
- brief details of the apparatus that you would use, the procedure that you would follow and the measurements that you would take,
- a sketch of the graph you would expect to obtain,
- how the data obtained from your graph would be used to determine
  - the percentage purity of NaC*l*O in **FA 7**,
  - the enthalpy change of reaction, ΔH_2, of reaction **2**.

You should assume that the specific heat capacity of the final solution is 4.18 J g^{-1} K^{-1} and that its density is 1.00 g cm^{-3}.

....[6]

(iv) With the aid of a suitable energy cycle, derive an expression for the enthalpy change of dissolution of NaC*l*O, ΔH_{sol}, in terms of ΔH_1 and ΔH_2.

[2]

[Total: 25]

3 Inorganic and Organic Analysis

(a) **FA 2** is an aqueous solution of $CuSO_4$.
FA 8 is a reducing agent.
FA 9 is a solution of ammonium vanadate(V), NH_4VO_3.

You are to perform the tests described in Table 3.1 and record your observations in the table.

In all tests, the reagents should be added gradually until no further change is observed unless you are instructed otherwise.

You should indicate clearly at which stage in a test a change occurs, recording your observations alongside the relevant tests. Your answers should include

- details of colour changes and precipitates formed
- the identities of gases evolved and details of the test used to identify each gas

Table 3.1

	tests	observations
(i)	Using a measuring cylinder, add 10 cm^3 of **FA 2** into a boiling tube. Add 4 spatulas of **FA 8**. Warm the mixture cautiously till boiling. Leave to cool for 5 minutes. Filter the mixture and keep the filtrate for tests **(ii)** and **(iii)**.	
(ii)	To 1 cm depth of the filtrate, add aqueous ammonia.	

Table 3.1

	tests	observations
(iii)	To another 1 cm depth of the filtrate, add 2 spatulas of solid ammonium chloride, followed by aqueous ammonia.	
(iv)	Using a measuring cylinder, transfer 2 cm^3 of **FA 9** into a boiling tube. Add 10 cm^3 of dilute sulfuric acid and swirl the mixture gently. The resultant yellow solution is **FA 10**, which is an acidified solution of VO_2^+.	
(v)	Using a spatula, add a **very small quantity** of **FA 8** to the boiling tube containing **FA 10** solution from test **(iv)**. Swirl the mixture gently and record your observations. Continue to add more **FA 8** in small quantities with swirling, until no further colour change is observed. Record all colour changes observed.	
	Filter the mixture and retain the filtrate for test **(vi)**.	
(vi)	To 1 cm depth of the filtrate from test **(v)**, add an equal volume of aqueous hydrogen peroxide.	

[6]

(b) **(i)** Complete Table 3.2 below, using the observations in Table 3.1**.**
In your answer, identify any gas and/or precipitate formed.

Table 3.2

identity of **FA 8**	evidence

[2]

(ii) With the aid of equation(s), explain your observation in test **(a)(iii)**.

……..

……..

……..

……..

……[2]

(iii) The half equations that represent the stepwise reduction of VO_2^+ ions are shown below.

Electrode reaction	$E^\ominus$ / V
$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$	+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

When excess aqueous ammonia is added to 1 cm depth of the filtrate in test **(a)(v)**, a grey precipitate is observed.

Given that the $E^\ominus$ value for **FA 8** is between −1.00 V to –0.50 V, state the identity of the grey precipitate.

………………………………………………………………………………………………………[1]

(c) Planning

The labels of four bottles of solutions in your school chemistry laboratory are found to be missing. They are aqueous solutions of Na_2CO_3, $Al_2(SO_4)_3$, CH_3COOH and CH_3CH_2CHO.

To identify the solutions in the unlabelled bottles, the following reagents are provided:

- **FA 2** which is an aqueous solution of $CuSO_4$,
- solution **X** which contains alkaline tartrate ions.

Fehling's solution can be prepared by mixing equal volumes of solution **X** and **FA 2**.

Using only the four unlabelled solutions, **FA 2** and solution **X**, you are to describe a detailed sequence of steps to identify each of the four solutions. Each of the solutions should be identified by at least one positive test.

Your plan should also state the expected observations, identities of any gas and/or precipitate formed and solutions identified at each step.

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[Total: 16]

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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 $\rightarrow$ (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) Colours 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

