Catholic Junior College

JC 2 Preliminary Examinations

Higher 2

CANDIDATE NAME	
CLASS	2T

CHEMISTRY

9729/04

Paper 4 Practical

Thursday 16 August 2018

2 hours 30 minutes

Candidates answer on the Question Paper

WORKED SOLUTIONS

This document consists of **14** printed pages.

[Turn over

1 **Z** is an oxidising agent. You are required to use a solution of iodine in potassium iodide to determine the mass of **Z** needed to liberate 1 mole of iodine from potassium iodide.

FA3 is an aqueous solution of iodine, I_2, in potassium iodide, KI.
FA4 is a 0.100 mol dm^{-3} aqueous sodium thiosulfate, $Na_2S_2O_3.5H_2O$.
FA5 is an aqueous solution containing 2.00 g dm^{-3} **Z**, an oxidising agent.

You are to follow the following procedure and record your results as instructed.

Titration 1

1 By using a pipette, transfer 25.0 cm^3 of **FA3,** an aqueous solution of iodine in potassium iodide, into a conical flask.
2 Titrate the iodine present with **FA4**, 0.100 mol dm^{-3} aqueous sodium thiosulfate, from a burette until the solution becomes colourless.
3 Repeat the titration as many times as you think necessary to obtain accurate results.
4 Record your results of titration in a suitable tabulated form below.

Titration of iodine in **FA3** with **FA4**

	Rough	Accurate		
Final burette reading /cm^3	**19.90**	**39.60**	**19.70**	
Initial burette reading /cm^3	**0.00**	**19.90**	**0.00**	
Volume of **FA4** used /cm^3	**19.90**	**19.70**	**19.70**	
		√	√	

Summary

25.0 cm^3 of **FA3** required **19.70** cm^3 of **FA4** for titration.

Show which results you used to obtain this value of the volume of **FA4** by placing a tick (√) under the readings used.

[5]

At least 2 sets of burette readings taken.
Burette readings recorded to 2 d.p.
Precision of V_{FA4} ± 0.10 cm^3 and correct average of V_{FA4} taken.

(a) Calculate how many moles of sodium thiosulfate were contained in the volume of **FA4** found necessary to react with 25.0 cm^3 of **FA3**.

Amount of $Na_2S_2O_3$ = $(\frac{19.70}{1000} \times 0.100)$ mol
= 1.97×10^{-3} mol
Moles of $Na_2S_2O_3$ = 1.97×10^{-3}

[1]

(b) Calculate how many moles of I_2 present in 25.0 cm^3 of **FA3** using the following equation for the reaction between iodine and thiosulfate ions.

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

Amount of I_2 = $(\frac{1}{2} \times 1.97 \times 10^{-3})$ mol
= 9.85×10^{-4} mol

Moles of I_2 = 1.97×10^{-3}

[1]

Titration 2

1 By using a pipette, transfer 25.0 cm^3 of **FA3,** an aqueous solution of iodine in potassium iodide, into a conical flask and then using a second pipette, add 25.0 cm^3 of **FA5**, an aqueous solution containing 2.00 g dm^{-3} of the oxidising agent, **Z**.

2 Titrate the total iodine present with **FA4**, 0.100 mol dm^{-3} aqueous sodium thiosulfate, from a burette as before until the solution becomes colourless.

3 Repeat the titration as many times as you think necessary to obtain accurate results.

4 Record your results of titration in a suitable tabulated form below.

Titration of total iodine now in **FA3** with **FA4**

	Rough	Accurate		
Final burette reading /cm^3	**29.70**	**29.50**	**29.50**	
Initial burette reading /cm^3	**0.00**	**0.00**	**0.00**	
Volume of **FA4** used /cm^3	**29.70**	**29.50**	**29.50**	
		√	√	

Summary

25.0 cm^3 of **FA3** to which 25.0 cm^3 of **FA5** had been added required **29.50** cm^3 of **FA4** for titration.

Show which results you used to obtain this value of the volume of **FA4** by placing a tick (√) under the readings used.

[3]

Precision of V_{FA4} ± 0.10 cm^3 and correct average of V_{FA4} taken.
Accuracy of titration results.

(c) Calculate how many moles of sodium thiosulfate were contained in the volume of **FA4** found necessary to react with the total iodine in the flask after 25.0 cm^3 of **FA3** and 25.0 cm^3 of **FA5** had been mixed.

Amount of $Na_2S_2O_3$ = ($\frac{29.50}{1000}$ x 0.100) mol
= 2.95 x 10^{-3} mol

Moles of $Na_2S_2O_3$ = 2.95 x 10^{-3}

[1]

(d) Calculate how many moles of I_2 present in the flask after 25.0 cm^3 of **FA3** and 25.0 cm^3 of **FA5** had been mixed.

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

Amount of I_2 = ($\frac{1}{2}$ x 2.95 x 10^{-3}) mol
= 1.475 x 10^{-3} mol

Moles of I_2 = 1.475 x 10^{-3}

[1]

(e) Calculate how many moles of I_2 were liberated from potassium iodide in the flask by 25.0 cm^3 of **FA5**.

[Turn over

Amount of I_2 liberated = (1.475×10^{-3} - 9.85×10^{-4}) mol
= 4.90×10^{-4} mol

Moles of I_2 = 4.90×10^{-3}
[2]

(f) Calculate the mass of **Z** present in 25.0 cm^3 of **FA5**.

Mass of Z = ($\frac{25.0}{1000}$ x 2.00) g
= 0.0500 g

Mass of Z = 0.0500 g
[1]

(g) Hence, from **(e)** and **(f)**, calculate the mass of **Z** needed to liberate 1 mole of I_2.

Mass of Z needed to liberate 1 mol of I_2 = ($\frac{0.0500}{4.90 \times 10^{-4}}$) g
= 102 g

Mass of Z = 102 g
[2]

[Total: 17]

2 You are required to determine the basicity of an acid by carrying out some experiments with aqueous sodium hydroxide.

FA1 is a 1.00 mol dm^{-3} aqueous sodium hydroxide, NaOH.
FA2 is a 1.00 mol dm^{-3} aqueous acid which is either monobasic with the formula **HA**, or dibasic with the formula **H_2A**.

By using the results of the following experiments, you are to going to determine the basicity of **FA2**.

You are to follow the following procedure and record your results as instructed.

Experiment 1

1. By using a measuring cylinder, pour 25 cm^3 of **FA1** into the Styrofoam cup provided and record the steady temperature. Rinse the thermometer with deionised water.
2. Use another 50 cm^3 measuring cylinder to measure 25 cm^3 of **FA2** and record its temperature.
3. Carefully add **FA2** to **FA1**, stir with the thermometer and record the highest temperature reached.
4. Record your results in the table provided below.

	Experiment 1	**Experiment 2**	**Experiment 3**
Initial temperature of **FA1** /°C	**31.0**	**31.0**	**31.0**
Initial temperature of **FA2** /°C	**31.0**	**31.0**	**31.0**
Highest temperature /°C	**37.9**	**35.6**	**40.1**
Mean initial temperature /°C	**31.0**	**31.0**	**31.0**
Temperature rise, ΔT /°C	**6.9**	**4.6**	**9.1**

Experiment 2
Thoroughly rinse out the Styrofoam cup with deionised water and repeat the experiment using 25 cm^3 of **FA1** and 50 cm^3 of **FA2**. Record your results in the table above.

Experiment 3
Thoroughly rinse out the Styrofoam cup with deionised water and repeat the experiment using 50 cm^3 of **FA1** and 25 cm^3 of **FA2**. Record your results in the table above.

(a) Complete the table of results by calculating the mean initial temperature of **FA1** and **FA2** for each of the three experiments. When calculating mean initial temperatures for **Experiments 2** and **3**, ignore the fact that the volumes mixed are unequal.

Fill in the corresponding rises in temperatures, ΔT in the table provided above.

[5]

Initial temperatures of FA1, FA2 & highest temperatures taken and recorded to 1 decimal place.
Correct mean initial temperatures recorded.
Correct ΔT recorded.

[Turn over

(b) Use your results to deduce the basicity of the acid.

From Expts 2 and 3 (Total volume of the reaction mixture is the same, 75 cm^3).

Expt 2: $NaOH(aq) + HA(aq) \longrightarrow NaA(aq) + H_2O(l)$
0.0250   0.0250   **0.0250 mol**

$2NaOH(aq) + H_2A(aq) \longrightarrow Na_2A(aq) + 2H_2O(l)$
0.0250   0.0125   **0.0250 mol**

Expt 3: $NaOH(aq) + HA(aq) \longrightarrow NaA(aq) + H_2O(l)$
0.0250   0.0250   **0.0250 mol**

$2NaOH(aq) + H_2A(aq) \longrightarrow Na_2A(aq) + 2H_2O(l)$
0.0500   0.0250   **0.0500 mol**

Since the rise in temperature, ΔT, is greater in Expt 3 as compared to that of Expt 2 (almost twice), FA2 is a dibasic acid, H_2A.

If the acid is monobasic, then the rise in temperature, ΔT, in Expts 2 and 3 should be the same.

[2]

(c) Write a full equation for the reaction between **FA1** and **FA2**. Do not omit spectator ions.

$2NaOH(aq) + H_2A(aq) \longrightarrow Na_2A(aq) + 2H_2O(l)$ **state symbols not required**

[1]

(d) Calculate the amount of heat evolved in **Experiment 1**.
Assume 4.3 J are required to raise the temperature of 1 cm^3 of solution by 1.0 ^oC.

Heat evolved = (50 x 4.3 x 6.9) J
= 1483.5 J

Heat evolved = 1483.5 J
[1]

(e) Using your answers to **(c)** and **(d)**, calculate the enthalpy of neutralisation, ΔH_n, per mole of water formed.

$2NaOH(aq) + H_2A(aq) \longrightarrow Na_2A(aq) + 2H_2O(l)$
0.0250   0.0125   0.0250 mol

$$\Delta H_n = -\left(\frac{1483.5}{0.0250}\right) \text{ J mol}^{-1}$$

$$= -59.3 \text{ kJ mol}^{-1}$$

$\Delta H_n = -59.3$ kJ mol^{-1}
[1]

Assessment of Planning Skills

You are provided with 150 cm^3 of each of three solutions, **FA6**, **FA7** and **FA8**. You are to identify which of these solutions correspond to the following solutions:

1 mol dm^{-3} sodium hydroxide, NaOH
2 mol dm^{-3} hydrochloric acid, HC*l*
1 mol dm^{-3} hydrochloric acid, HC*l*

You are also provided with the following apparatus:

A thermometer
A Styrofoam cup
2 measuring cylinders

You are to plan a simple experiment which will allow an identification of the three solutions to be made, using only the apparatus and materials listed above and deionised water. (Note that you are **not** provided with any pH indicator).

You are **not** required to carry out the plan but you have to present your results in an appropriate manner based on your plan so that the identification can be made.

PLAN

1 **Using a measuring cylinder, pour 30 cm^3 of FA6 into the Styrofoam cup provided and record its temperature using the thermometer. Rinse the thermometer with deionised water.**

2 **Using another measuring cylinder to measure 30 cm^3 of FA7 and add it to FA6 in the Styrofoam cup. Stir, using the thermometer and record the highest temperature rise.**

3 **Thoroughly rinse out the Styrofoam cup with deionised water and repeat the Expt using 30 cm^3 of FA6 and 30 cm^3 of FA8.**

4 **Thoroughly rinse out the Styrofoam cup with deionised water and repeat the Expt using 30 cm^3 of FA7 and 30 cm^3 of FA8.**
(Refer to table 1 in results. The base, NaOH can be identified.)

5 **Thoroughly rinse out the Styrofoam cup with deionised water and repeat the Expt using 30 cm^3 of FA6 and 15 cm^3 of FA7.**

6 **Thoroughly rinse out the Styrofoam cup with deionised water and repeat the Expt using 30 cm^3 of FA6 and 15 cm^3 of FA8.**
(Refer to table 2 in results. The acid, HC*l* of higher concentration can be identified.)

(Note: Specific volumes must be mentioned and the permutations of the respective solutions must be evident enough to allow identification possible. However, the total volume used for each of the three solutions used cannot exceed 150 cm^3 given.)

[5]

[Turn over

RESULTS

Table 1

V_{FA6} /cm^3	30	30	-
V_{FA7} /cm^3	30	-	30
V_{FA8} /cm^3	-	30	30
ΔT /°C	T1	T1	No change

FA7 + FA8, no change in temperature, so they do not react with each other. So, FA7 and FA8 are both acids.

Therefore, FA6 is NaOH.

Table 2

V_{FA6} /cm^3 (base)	30	30
V_{FA7} /cm^3	15	-
V_{FA8} /cm^3	-	15
ΔT /°C	T1	T2

Assume that T1 > T2.

Since the rise in temperature is higher for reaction between FA7 and the base, therefore FA7 is HC*l* of higher concentration (2 mol dm^{-3}).

$$\underset{0.0300}{\overset{\text{FA6}}{NaOH(aq)}} + \underset{0.0300}{\overset{\text{FA7}}{HCl(aq)}} \longrightarrow NaCl(aq) + \underset{0.0300\text{ mol}}{H_2O(l)}$$

$$\underset{0.0150}{\overset{\text{FA6}}{NaOH(aq)}} + \underset{0.0150}{\overset{\text{FA8}}{HCl(aq)}} \longrightarrow NaCl(aq) + \underset{0.0150\text{ mol}}{H_2O(l)}$$

[3]

[Total: 18]

3 You are to determine the identity of **FA9**.

Carry out the following experiments on the solid **FA9** which contains the **sodium cation** and **one anion** from the following list: CO_3^{2-}, Cl^-, Br^-, I^-, NO_3^-, NO_2^-, SO_4^{2-} and SO_3^{2-}.

In all tests, reagents should be added gradually until no further change is observed, with shaking after each addition.

Record your observations you make from them in the spaces provided.

Your answer should include
(i) details of colour change and precipitated formed, if any;
(ii) the identity of gases evolved, if any, and details of the test used to identify the gas.

You should indicate clearly at what stage in a test a change occurs.

No additional or confirmatory tests for ions present should be attempted.

Test	Observation [9]
(a) Place one third of the solid **FA9** in a test-tube and heat strongly until the solid melts and a gas is given off.	**FA9 melts to give a yellow liquid which then resolidifies to a give a white solid. Effervescence observed.**
Identify the gas evolved.	**Gas evolved rekindles/relights a glowing splint. O_2 liberated.**
Continue the strong heating for 2-3 minutes then leave the tube to cool and retain the residue for test (d).	**White residue.**
Melt a second sample of **FA9** and heat for 2-3 minutes. Leave this to cool and retain for test (h).	
(b) Using a dropper, place 1 cm depth of aqueous of sodium hydroxide into a test-tube and tip into it the remaining solid **FA9**.	**FA9 dissolves / no ppt.**
Warm gently and retain for test (c).	**Damp red litmus, no change. No NH_3 gas liberated.**
(c) Cool the test-tube and solution from (b).	
Add a half spatula full of aluminium powder and warm gently.	**Gas liberated turns damp red litmus blue. NH_3 gas evolved.**

[Turn over

Test	Observation
(d) Dissolve the residue from (a) in deionised water about 3 cm depth and divide the solution into three parts. Use these tests for (e) to (g).	
(e) To one part of the solution from (d), add aqueous potassium iodide followed dilute sulfuric acid.	**Brown solution / iodine liberated.**
(f) To the second part of the solution from (d), add aqueous potassium manganate(VII) followed by dilute sulfuric acid.	**Purple acidified $KMnO_4$ is decolourised.**
(g) To the third part of the solution from (d), add aqueous sodium hydroxide and a half spatula full of aluminium powder. Warm gently.	 **Gas liberated turns damp red litmus blue. NH_3 gas evolved.**
(h) Take the second sample of solid, heated **FA9** that you prepared in (a). Add to dilute sulfuric acid and warm gently.	 **Brown fumes liberated.**

[9]

What anion is present in **FA9** before it is heated? **NO_3^-**

What anion is present in **FA9** after it is heated? **NO_2^-**

In test (e), the anion is behaving as **an oxidising agent**.

In test (f), the anion is behaving as **a reducing agent**.

[4]

Hence, write a balanced chemical equation for the thermal decomposition of **FA9**.

$$NaNO_3(s) \longrightarrow NaNO_2(s) + \tfrac{1}{2} O_2(g)$$

[1]

Assessment of Planning Skills

Each of the solutions **FA10**, **FA11** and **FA12** contains one of the cations Al^{3+}, Mg^{2+} and Zn^{2+} ions but not in that order.

You are provided with a set of test-tubes and the following reagents:

Aqueous ammonia, NH_3
Dilute hydrochloric acid, HCl
Aqueous sodium carbonate, Na_2CO_3
Aqueous sodium hydroxide, NaOH

You are required to devise and perform an experiment which will enable you to identify the cation present in each of the solutions **FA10**, **FA11** and **FA12**. You may only use any of the reagents provided above and **no** other reagent. **You should aim to use the minimum number of reactions**, where possible.

This space below is for you to plan your steps which should then be recorded, together with the observations you make in the table in the next page.

PLAN

1 **Add aqueous ammonia, NH_3 till excess to separate samples of the 3 solutions. If a white ppt is obtained and dissolves in excess NH_3, suggests the presence of Zn^{2+}.**

2 **Add aqueous sodium hydroxide, NaOH till excess to separate samples of the remaining 2 solutions.**

If a white ppt is obtained and dissolves in excess NaOH, suggests the presence of Al^{3+}, if insoluble in excess NaOH, Mg^{2+}.

[2]

In the table below, record all of your observations, and the identity of a cation as soon as this is established.

Reagent added	Observations and identities of cations		
	FA10	FA11	FA12
NH_3(aq)	**White ppt soluble in excess.** **Zn^{2+}**	**-**	**-**
NaOH(aq)	**-**	**White ppt soluble in excess.** **Al^{3+}**	**White ppt insoluble in excess.** **Mg^{2+}**

[3]

[Turn over

Deduction

Solution **FA10** contains the cation **Zn^{2+}**

Solution **FA11** contains the cation **Al^{3+}**

Solution **FA12** contains the cation **Mg^{2+}**

[1]

[Total: 20]

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

[Turn over

(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) Tests 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