Name:		Shift:	
Class:		Laboratory:	

ST ANDREW'S JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

PAPER 4 PRACTICAL

Chemistry **28 August 2018**

Higher 2 **2 hours 30 minutes**

READ THESE INSTRUCTIONS FIRST.

Write your name and class on all the work you hand in.
Give details of the practical shift and laboratory in the boxes provided above.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** the 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 16 and 17.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
Total	

This document consists of **17** printed pages including this page.

Answer all the questions in the spaces provided.

1 Determination of percentage by mass of sodium carbonate in a mixture of sodium carbonate and sodium hydrogen carbonate

The complete reaction between sodium carbonate and hydrochloric acid can be represented as shown:

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

However, when sodium carbonate is titrated against hydrochloric acid, it reacts with hydrochloric acid in two separate stages.

$Na_2CO_3 + HCl \rightarrow NaCl + NaHCO_3$ ---------------- ***reaction 1***

$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$ ---------------- ***reaction 2***

When a mixture of sodium carbonate and sodium hydrogen carbonate is titrated against hydrochloric acid using thymolphthalein indicator, the blue colour of the indicator is discharged when sodium carbonate is partially neutralised as represented by ***reaction 1***.

Screened methyl orange is then added and a further quantity of hydrochloric acid is necessary to bring about a colour change when ***reaction 2*** is complete. This further amount of acid reacts with both the sodium hydrogen carbonate formed in ***reaction 1*** as well as the sodium hydrogen carbonate present initially in the mixture.

(a) In this experiment, you will determine the amount of Na_2CO_3 and $NaHCO_3$ in **FA 1** by following the procedures below.

FA 1 is a solution containing sodium carbonate, Na_2CO_3 and sodium hydrogen carbonate, $NaHCO_3$.

FA 2 is an aqueous solution containing 0.50 mol dm^{-3} of hydrochloric acid, HCl.

1. Pipette 25.0 cm^3 of **FA 1** into a conical flask.

2. Add 5 drops of thymolphthalein indicator and titrate **FA 1** against **FA 2** in a burette.

3. When the blue colour is discharged, note and record the burette reading in the table provided on page 3. This end-point may not be easily seen. Therefore, you are advised to put a white tile under your conical flask to help you. If you are unsure if the blue colour has discharged or not, you may also add a few more drops of thymolphthalein to the solution.
   Do not discard this mixture!
   *(The volume of **FA 2** required to reach the first end-point need not be consistent but it should not exceed 15 cm^3.)*

4. Add 3 drops of screened methyl orange to this mixture and **continue** the titration until the second end-point is reached. Record the final burette reading in the same table provided on page 3.

5. Perform sufficient titrations to obtain consistent results for the **second end-point**, which is the total volume of **FA 2** required.

Results

	1	2	3	
Final burette reading (with screened methyl orange) / cm^3	30.80	40.50	30.60	
Final burette reading (with thymolphthalein) / cm^3	12.50	22.10	12.30	
Initial burette reading / cm^3	0.00	10.00	0.00	
Total volume of **FA 2** used to reach the second end-point / cm^3	30.80	30.50	30.60	
Place a tick for the consistent results		✓	✓	

[4]

[2] for accuracy of total volume of FA 2

[1] for 2 dp for all burette readings

[1] for correct sequence of burette readings, putting ticks for two total volume of FA 2 that are within 0.10 cm^3

(b) ***x*** is the average volume of **FA 2** required to reach the first end point.

y is the average **further** volume of **FA 2** required to reach the second end-point.

From your 2 consistent titration results, calculate ***x*** and ***y***.

x = (12.10 + 12.30) / 2 = 12.20 (cm^3)

$$y = \frac{(40.50 - 22.10) + (30.60 - 12.30)}{2} = \frac{18.40 + 18.30}{2} = 18.35\ (cm^3)$$

[1] for correct calculations of x from the results in (a), in 2 dp
[1] for correct calculations of y from the results in (a), in 2 dp

x = ………………………

[2]

y = ………………………

(c) **(i)** Using ***x***, calculate the amount, in moles, of Na_2CO_3 in 25.0 cm^3 of **FA 1**.
ecf from (b); 0m if never use answer from (b)

No of moles of HC*l* = 12.20/1000 x 0.50 = 6.10 x 10^{-3} mol
No of moles of Na_2CO_3 = 6.10 x 10^{-3} mol **[1]**

Number of moles of Na_2CO_3 = ………………………

[1]

(c) **(ii)** Using ***y***, calculate the total amount, in moles, of $NaHCO_3$ in the reaction mixture.

ecf from (b); 0m if never use answer from (b)

No of moles of HC*l* = 18.35/1000 x 0.50 = 9.18×10^{-3} mol

Total no of moles of $NaHCO_3$ = 9.18×10^{-3} mol **[1]**

Total number of moles of $NaHCO_3$ = ……………………… **[1]**

(d) From your answers in **(c)**, calculate the amount, in moles, of $NaHCO_3$ in 25.0 cm^3 of **FA 1**.

No of moles of $NaHCO_3$ formed from Na_2CO_3 = 6.10×10^{-3} mol

No of moles of $NaHCO_3$ in **FA 1** = $9.18 \times 10^{-3} - 6.10 \times 10^{-3}$

= 3.08×10^{-3} mol **[1]**

i.e (c)(ii) – (c)(i)

Number of moles of $NaHCO_3$ = ………………………

[1]

(e) Calculate the percentage by mass of sodium carbonate in **FA 1**, which is a mixture of $NaHCO_3$ and Na_2CO_3.

[A_r: Na, 23.0; H, 1.0; C, 12.0; O, 16.0]

Mass of $NaHCO_3$ in **FA 1** = 3.08×10^{-3} x 84.0 **i.e ((d) x 84)**

= 0.259 g

Mass of Na_2CO_3 in **FA 1** = 6.10×10^{-3} x 106.0 **i.e ((c)(i) x 106)**

= 0.647 g

[1] for correct calculation of mass of $NaHCO_3$ and Na_2CO_3

% by mass of Na_2CO_3 in **FA 1** = 0.647 / (0.647 + 0.259) x 100%

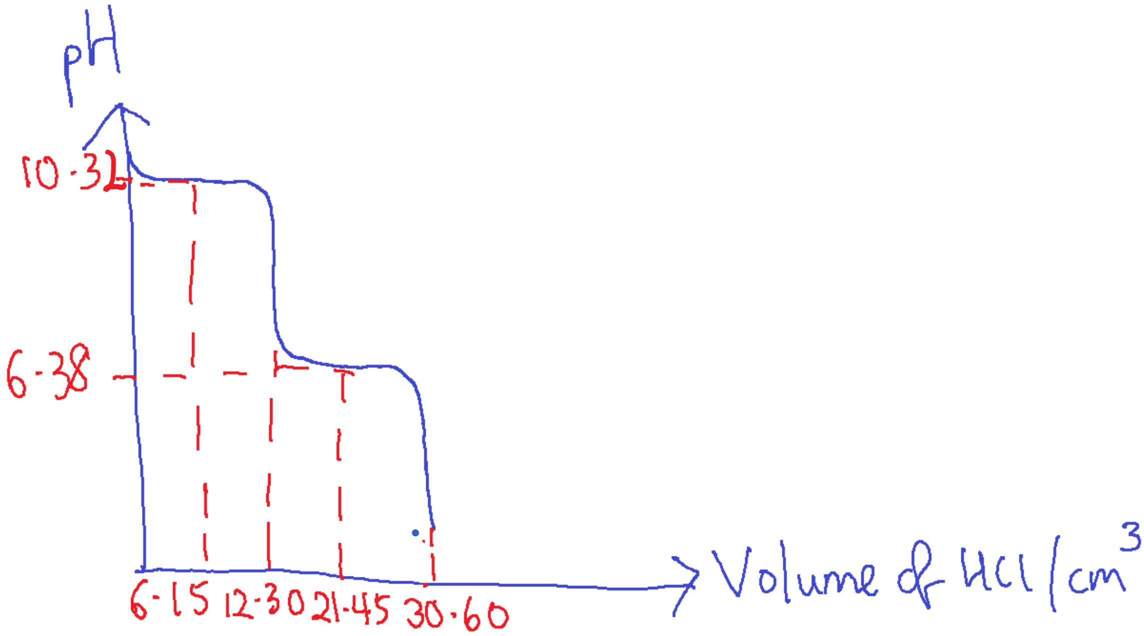
= 71.4 % **[1]** **[2]**

Apply ecf within part if student use wrong Mr for calculation of mass

(f) A student decides to carry out the same experiment in **(a)** by using a pH meter to determine the percentage by mass of Na_2CO_3 in the mixture.

Given that pK_b of CO_3^{2-} = 3.68 and pK_b of HCO_3^- = 7.62, sketch a graph to show how the pH of the mixture changes as HC*l* is added. You may use your titre values in any set of experiments obtained in **(a)** for the volume of HC*l* at the two equivalence points.

[2]



[1] for correct shape in the right direction with correct axes and unit

[1] for correct labelling of volumes at MBCs, pH at MBCs, 2 equivalence volumes using any set of titre volumes (including x and y)

Planning

(g) Unlike Group 2 carbonates, solid sodium carbonate, Na_2CO_3, does **not** decompose on heating with a Bunsen burner. However, for solid sodium hydrogencarbonate, $NaHCO_3$, it will form sodium carbonate, steam and carbon dioxide when heated.

(i) Write an equation, with state symbols, to represent the thermal decomposition of sodium hydrogen carbonate.

$2\,NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$ **[1]**

Mole ratio 1 : ½ : ½ : ½ is acceptable

.... **[1]**

(g) **(ii)** Given the above information, you are to devise a plan to determine the percentage by mass of $NaHCO_3$ in a solid mixture of $NaHCO_3$ and Na_2CO_3.

You may assume you are provided with

- a boiling tube
- a pair of tongs
- 10 g of $NaHCO_3$ and Na_2CO_3 solid mixture
- a heat resistant mat
- equipment normally found in a school or college laboratory

In your plan, you should include details of:

- procedure you would follow, including the apparatus you would use and the safety precautions to take,
- measurements you would take,
- a brief outline of how the results can be used to determine the percentage by mass of $NaHCO_3$ in the mixture. You may make assumptions for the masses involved and use appropriate molar mass values to solve this.
[A_r: Na, 23.0; H, 1.0; C, 12.0; O, 16.0]

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……………………………………………………………………………………………… **[6]**

Procedure **[4]**

1. Weigh the dry empty boiling tube using a weighing balance.
2. **Place 10 g (or any mass as defined) of sample powder in the boiling tube and weigh again**. Record the mass reading.
3. Using the tongs provided, **gently heat** the boiling tube with the sample using a Bunsen burner for about 2-3 minutes, **before strongly heating** the tube for another 5 minutes.
4. **Cool the boiling tube on a heat resistant mat before weighing the tube and sample**. Record the mass reading.
5. **Repeat the heat-cool-weigh process till consistent mass** is obtained.

Treatment of results:

Let the mass of solid mixture used be 10 g

Let the final mass (of Na_2CO_3) obtained be y g

Mass of H_2O and CO_2 = (10 – y) g

Mass of 1mol of H_2O and 1 mol of CO_2 = 18.0 + 44.0 = 62.0 g

Amount of H_2O and CO_2 evolved = 2(10 – y) / 62.0 mol **[1]**

= amount of $NaHCO_3$

OR

Amount of H_2O and CO_2 evolved = (10 – y) / 62.0 mol **[1]**

Amount of $NaHCO_3$ = 2(10 – y) / 62.0 mol

Mass of $NaHCO_3$ = [2(10 – y) / 62] x 84 g

% by mass = $\frac{84(10-y)}{31 \times 10}$ x 100% **[1]**

[Total: 20]

2 Determination of n in the complex ion formula $[Cu(NH_3)_n]^{2+}$

Many transition metal ions possess the ability to form complexes with ligands, which can either be organic or inorganic molecules/ions.

In this experiment, you will determine the value of n in the formula $[Cu(NH_3)_n]^{2+}(aq)$, which is the complex ion formed when aqueous NH_3 is added to $Cu^{2+}(aq)$.

Different volumes of $CuSO_4$ solution and aqueous ammonia are mixed and the corresponding temperature changes are measured.

FA 3 is 0.5 mol dm^{-3} $CuSO_4$ solution
FA 4 is 2.0 mol dm^{-3} aqueous ammonia

(a) Measure and record the temperatures of the given solutions **FA 3** and **FA 4**.

$T_{FA\ 3}$ = ...27.6..........°C

$T_{FA\ 4}$ = ...26.6..........°C **[1]**

[1] for temperatures recorded to 1 dp.

(b) Carry out the following procedures and prepare a table for your results on **page 8**.
Your table should include i) $V_{FA\ 3}$, ii) $V_{FA\ 4}$, iii) $T_{initial}$, iv) T_{max}, v) temperature rise, ΔT and vi) colour of solution and precipitate (if any).

Procedures:

Experiment 1

- Measure 9.00 cm^3 of **FA 3** from a burette into a boiling tube.
- Add into the boiling tube 1.00 cm^3 of **FA 4** from another burette.
- Note the temperature rise while stirring to ensure that you do not miss the highest temperature reached. Record this temperature as T_{max}.
- Note and record the colour of precipitate (if any) and the colour of solution observed.
- Discard the content in the boiling tube and wash the boiling tube thoroughly. Wipe the thermometer dry for use in **experiment 2**.

Experiment 2

- Measure 8.00 cm^3 of **FA 3** from a burette into the boiling tube.
- Add into the boiling tube 2.00 cm^3 of **FA 4** from another burette.
- Note the temperature rise while stirring to ensure that you do not miss the highest temperature reached. Record this temperature as T_{max}. Note and record the colour of precipitate (if any) and the colour of solution observed.
- Discard the content in the boiling tube and wash the boiling tube thoroughly. Wipe the thermometer dry for use in subsequent experiments.

Experiments 3 - 9

Perform 7 more experiments, each time reducing the volume of **FA 3** by 1.00 cm^3 but increasing the volume of **FA 4** by 1.00 cm^3 such that the total volume of solution is kept constant at 10.00 cm^3.

Expt	**$V_{FA\,3}$ / cm^3**	**$V_{FA\,4}$ / cm^3**	**$T_{initial}$ / °C**	**T_{max} / °C**	**ΔT / °C**	**Observation**
1	9.00	1.00	27.5	28.4	0.9	(pale) blue ppt
2	8.00	2.00	27.4	28.9	1.5	(pale) blue ppt
3	7.00	3.00	27.3	29.4	2.1	(pale) blue ppt
4	6.00	4.00	27.2	29.4	2.2	(pale) blue ppt
5	5.00	5.00	27.1	29.7	2.6	(pale) blue ppt in deep blue solution
6	4.00	6.00	27.0	29.3	2.3	Deep blue solution
7	3.00	7.00	26.9	28.9	2.0	Deep blue solution
8	2.00	8.00	26.8	28.5	1.7	Deep blue solution
9	1.00	9.00	26.7	27.9	1.2	Deep blue solution

g

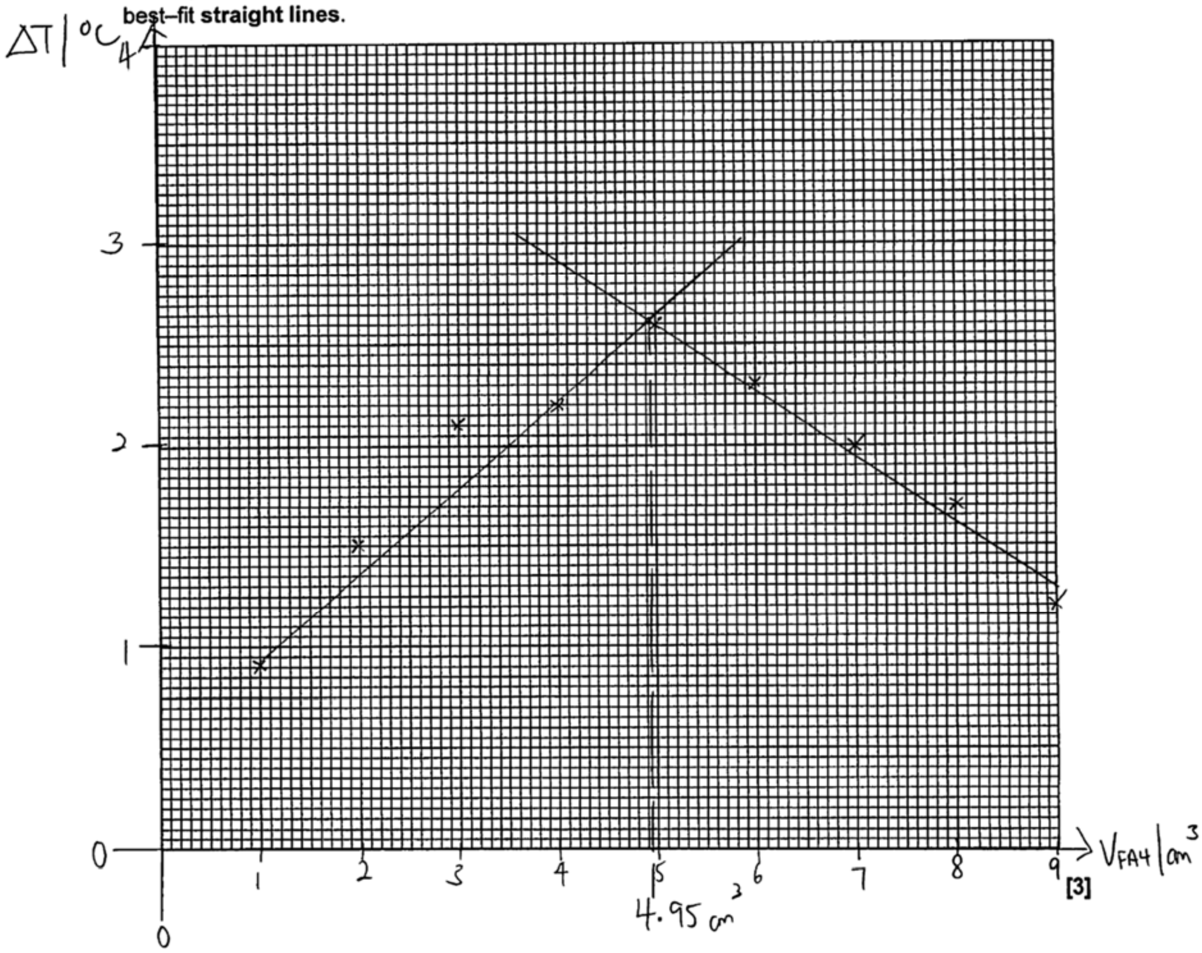
[5]

[1] for correct header (expt number not needed) with units
[1] for correct decreasing $V_{FA\,3}$ and increasing $V_{FA\,4}$ in 2 dp
[1] for 1 dp for T_{max} and ΔT; 1 dp / 3 - 4 sf for $T_{initial}$
[1] correctly calculated $T_{initial}$ and ΔT
[1] for observations changing from (pale) blue ppt [ONLY PURE BLUE, no greenish-blue] to (deep / dark) blue solution (doesn't matter where there's a change, as long as the trend is right; There should not be any ppt in expt 8 or 9)

(c) Plot a graph of temperature rise, ΔT, against volume of **FA 4**. Your plot should consist of **two** best-fit **straight lines**.

[3]

(c) Plot a graph of temperature rise, ΔT, against volume of **FA 4**. Your plot should consist of **two** best–fit **straight lines**.



[3]

[1] Axes labelled correctly with units, min and max points cover more than half the space in both directions, no awkward scale

[1] points plotted correctly to within half a small square (2 points before and 2 points after intersection)

[1] 2 lines of best fit with intersection

(d) (i) Show on your graph how the volume of **FA 4** that corresponds to the highest temperature rise can be determined.

[1] for extrapolating vertical line from x-axis to point of intersection / show coordinates at point of intersection + point correctly read to within ½ small square for volume of FA 4

Volume of **FA 4** with highest temperature rise = 4.95 cm^3

Hence, calculate the volume of **FA 3** that corresponds to this volume of **FA 4**.
Volume of **FA 3** = 10.00 – 4.95 = 5.05 cm^3

[1] for correct calculation of volume of FA 3

[1] for accuracy (see (c)(iv) 3.51 < n < 4.49)

Volume of **FA 3** = $\boxed{5.05}$ .... cm^3 **[3]**

(ii) Calculate the amount, in moles, of aqueous ammonia in the volume of **FA 4** with the highest temperature rise.

Amount of NH_3 = 4.95 /1000 x 2.0 = 9.90 x 10^{-3} mol **[1]**

Amount of $NH_3(aq)$ = ... **[1]**

(iii) Calculate the amount, in moles, of Cu^{2+} ions in the volume of **FA 3** that you have determined in **(i)**.

Amount of Cu^{2+} = 5.05 /1000 x 0.5 = 2.53 x 10^{-3} mol **[1]**

Amount of $Cu^{2+}(aq)$ = ... **[1]**

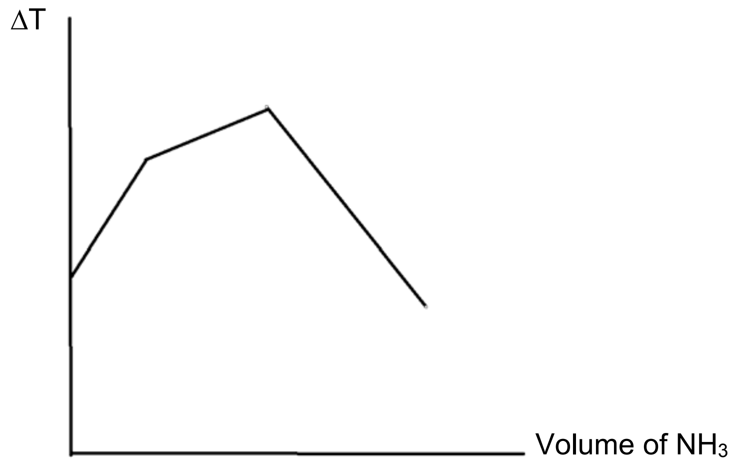
(iv) Calculate the number of moles of NH_3 bonded with one mole of Cu^{2+} ions in the solution and hence, deduce the value of n in the formula $[Cu(NH_3)_n]^{2+}$.

Amount of NH_3 = 9.90 x 10^{-3} mol
NH_3 : Cu^{2+} = 9.90 x 10^{-3} : 2.53 x 10^{-3} = 3.91 : 1
n = 4 **[1]**
Do not award if n is not a whole number.

[1]

n = ...

(e) The graph of ΔT against volume of NH_3 should theoretically look like the one below, with a combination of two straight lines with different positive gradients before the change in temperature starts to decrease.



With reference to the observations that you have recorded in the table on page 8, explain, with the aid of two relevant equations, why the graph is a combination of two straight lines with different positive gradients.

There were **two reactions** which produces different amount of heat / different enthalpy change of reaction. **[1]**

$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$
OR $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$ **[1]**

$Cu(OH)_2 + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+} + 2OH^-$ **[1]**
OR $Cu^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+}$ OR $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+} + 6H_2O$

Accept if students use their calculated n value. .. **[3]**

(f) Suggest an improvement that you will make to this experiment to improve the accuracy of the results obtained.

Use a rubber bung with a hole (for the thermometer to be inserted) to cover the boiling tube immediately after the two reagents are mixed so as to prevent heat loss to surrounding. **[1]**
OR
Dry the boiling tube before each experiment so that the residual water will not add on to the total volume of solution and cause a lower temperature rise. **[1]**
OR
Mix the solutions in a Styrofoam cup (with a lid) to prevent heat loss to the surrounding. **[1]**

... **[1]**

Planning

(g) Chromium cations can also form complexes. A student was given a solid which has a formula of either $[Cr(H_2O)_5Cl]Cl_2$ or $[Cr(H_2O)_4Cl_2]Cl$. The relative formula mass of the compound is 248.5.

When dissolved in water, the chloride ions not involved in the complex ion would be liberated into the solution.

$$[Cr(H_2O)_5Cl]Cl_2(s) \rightarrow [Cr(H_2O)_5Cl]^{2+}(aq) + 2Cl^{-}(aq)$$

$$[Cr(H_2O)_4Cl_2]Cl(s) \rightarrow [Cr(H_2O)_4Cl_2]^{+}(aq) + Cl^{-}(aq)$$

To determine the formula of the solid given, a student prepared a 250 cm^3 of standard solution using 29.80 g of the given solid. He then determined the amount of free chloride ions by titrating 25.0 cm^3 of the standard solution against 0.3 mol dm^{-3} silver(I) nitrate solution while using some potassium chromate(VI) as an indicator. When silver(I) nitrate solution was added, a white precipitate of AgCl was formed.

$$Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$$

When all the free chloride ions had precipitated, a red-brown precipitate of silver chromate(VI) was formed to signify that the end-point had been reached.

(i) The teacher commented that the student should have reduced the mass of solid used by half for the preparation of standard solution.
Explain, with the aid of suitable calculations, why 29.80 g is not a suitable mass to be used. **[2]**

Amount of solid in 250 cm^3 = 29.80 / 248.5 = 0.1199 mol

If solid has formula $[Cr(H_2O)_5Cl]Cl_2$,

Amount of Cl^{-} in 25.0 cm^3 = 0.1199 x 25.0/250 x 2 = 0.02398 mol

Amount of $AgNO_3$ needed = (0.02398 / 0.3) x 1000 = 79.9 cm^3 **[1]**

Since the volume required is more than a burette full or > 50.00 cm^3, the mass is not suitable. **[1]**

(g) (ii) You are to describe how the student should prepare the standard solution by using his teacher's proposal.

In your answer, include
- the procedures involved in the preparation of the standard solution,
- the apparatus and equipment used to prepare the standard solution. **[2]**

Procedure [2]

Using a **weighing balance**, weigh accurately about 14.90 of the unknown solid.

Tip/transfer the solid into a **small beaker and reweigh the emptied weighing bottle**.

Add some **deionised water to dissolve the solid**.

Transfer the solution into a **250 cm^3 volumetric flask** carefully and **top up to the mark using deionised water**.

Stopper and shake well to obtain a homogeneous solution.

[Total: 23]

3 Identifying cations in an unknown sample

(a) You are given **FA 5**, which is an aqueous solution containing two cations and one anion. One of the cations is Cu^{2+}. The other cation can be found from the list in the **Qualitative Analysis Notes** provided on page 16.

Perform the tests described in Table 3.1. Record your observations in the table. In all the tests, the reagent should be added gradually until no further change is observed, with shaking after each addition. Test and identify any gases evolved. No additional or confirmatory tests for ions present should be attempted.

Table 3.1

	Tests	Observations
1.	To 1 cm depth of **FA 5**, add 2 cm depth of **FA 1** (from question 1).	Green solution turned brown which eventually turned yellow-green. **Effervescence / Bubbling / Gas** [1/2] is observed. The **gas formed white ppt with $Ca(OH)_2$(aq)**. [1/2] The gas is CO_2.
2.	Add about 3 cm^3 of dilute aqueous ammonia to 1 cm^3 of **FA 5.** Filter the mixture and note the appearance of both the filtrate and residue. Add dilute sulfuric acid dropwise to the filtrate till in excess.	Reddish-brown ppt is formed. The solution turned from (dark) green to dark blue. The **residue is brown (can accept reddish-brown)** [1/2] and the **filtrate is (deep / dark) blue**. [1/2] **(Light) blue ppt** [1/2] is formed upon dropwise addition of H_2SO_4. **Ppt dissolves to form a very light blue / colourless solution** in excess H_2SO_4. [1/2]
3.	Add a spatula of solid potassium iodide to 3 cm^3 of **FA 5.** Filter the mixture and note the appearance of the filtrate. Add 1 cm^3 of hexane to the filtrate and shake well.	The **filtrate is green / yellow** [1/2], residue contains black and off-white ppt. 2 immiscible layers are formed. The **top layer is pink / violet / purple in colour** [1] **and the bottom layer is green / yellow**. [1/2]

[5]

(b) Consider your observations in Table 3.1.

(i) State the other cation which is present in **FA 5**.

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

Fe^{3+} **[1]**

Do not accept H^+

(ii) **FA 5** turns Universal Indicator paper red. With reference to this and your observations in test 1, write an ionic equation to represent the reaction between **FA 1** and **FA 5**.

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

$2\,H^+\,(aq) + CO_3^{2-}\,(aq) \rightarrow CO_2\,(g) + H_2O\,(l)$ **[1]** OR

$H^+\,(aq) + HCO_3^-\,(aq) \rightarrow CO_2\,(g) + H_2O\,(l)$ **[1] (no need state symbols)**

(iii) With reference to test 3, suggest the identity of the species which was responsible for the observations seen when hexane was added to the filtrate. Hence, suggest the property of **FA 5**.

……………………………………………………………………………………………………… **[2]**

I_2 **[1]**

FA 5 is oxidising / can be reduced. **[1]**

Planning

(c) **FA 5** also contains an anion. To determine the identity, a student heated **FA 5** with A*l* and NaOH(aq). A gas was evolved and it turned moist red litmus paper blue.

(i) Based on the observations given, state the possible identities of the anions.

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

NO_3^- and NO_2^- **[1]**

(ii) You are provided with the reagents NaOH(aq), NH_3(aq), HNO_3(aq) and $AgNO_3$(aq).

Suggest a test to confirm the identity of the anion in **FA 5**. State the expected observations.

DO NOT carry out the test.

Test: ………………………………………………………………………………………………

………

Expected observation for each of the possible anions in **(i)**.

………

……… **[2]**

Add HNO_3 (aq) (dropwise) to **FA 5**. **[1]**

If brown gas is observed, NO_2^- is present. **[1]**

If no brown gas is seen, NO_3^- is present.

[Total: 12]

~ END OF PAPER ~

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

ion	*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 on warming 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