Cambridge International AS & A Level

**Cambridge International Examinations**
Cambridge International Advanced Subsidiary and Advanced Level

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|---|---|---|---|---|---|---|
| CANDIDATE NAME | | | | | | |
| CENTRE NUMBER | | | | | CANDIDATE NUMBER | |

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**CHEMISTRY** **9701/35**

Paper 3 Advanced Practical Skills 1 **October/November 2014**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.
Give details of the practical session 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.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

Qualitative Analysis Notes are printed on pages 12 and 13.

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.

| **Session** |
|---|
| |
| **Laboratory** |
| |

| **For Examiner's Use** | |
|---|---|
| **1** | |
| **2** | |
| **3** | |
| **Total** | |

This document consists of **13** printed pages and **3** blank pages.

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CAMBRIDGE International Examinations

**[Turn over**

1 In this experiment you are to determine **x** in the formula of hydrated sodium carbonate, $Na_2CO_3.\mathbf{x}H_2O$, by titration.

**FA 1** is aqueous sodium carbonate, $Na_2CO_3$, containing 150.0 g of solid $Na_2CO_3.\mathbf{x}H_2O$ in each $dm^3$ of solution.
**FA 2** is 0.110 mol $dm^{-3}$ nitric acid, $HNO_3$.
methyl orange indicator

**(a) Method**

**Diluting the solution of FA 1**

- Pipette 25.0 $cm^3$ of **FA 1** into the 250 $cm^3$ volumetric (graduated) flask.
- Make the solution up to the mark using distilled water.
- Shake the flask thoroughly to mix the solution before using it for your titrations.
- This solution of sodium carbonate is **FA 3**.
- Rinse the pipette with distilled water.

**Titration**

- Pipette 25.0 $cm^3$ of **FA 3** into a conical flask.
- Fill the burette with **FA 2**.
- Add several drops of methyl orange indicator to the conical flask.
- Carry out a **rough** titration and record your burette readings in the space below.

The rough titre is ................ $cm^3$.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 2** added in each accurate titration.

| | |
|---|---|
| I | |
| II | |
| III | |
| IV | |
| V | |
| VI | |
| VII | |

[7]

**(b)** From your accurate titration results, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

volume of **FA 2** = ................ $cm^3$
[1]

**(c) Calculations**

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

**(i)** Calculate the number of moles of nitric acid in the volume of **FA 2** calculated in **(b)**.

moles of $HNO_3$ = ..................... mol

**(ii)** Complete the equation below and include the missing state symbols.

$Na_2CO_3(aq)$ + $HNO_3(aq)$ $\rightarrow$ $NaNO_3$ + $CO_2$ + $H_2O$

**(iii)** Calculate the number of moles of sodium carbonate in 25.0 $cm^3$ of solution **FA 3**.

moles of $Na_2CO_3$ in 25.0 $cm^3$ of **FA 3** = ....................... mol

**(iv)** Calculate the number of moles of sodium carbonate in 250.0 $cm^3$ of solution **FA 3**.

moles of $Na_2CO_3$ in 250.0 $cm^3$ of **FA 3** = ....................... mol

**(v)** Use the information on page 2 and your answer to **(iv)** to calculate the relative formula mass, $M_r$, of hydrated sodium carbonate, $Na_2CO_3.\mathbf{x}H_2O$.

$M_r$ of $Na_2CO_3.\mathbf{x}H_2O$ = ................................

**(vi)** Calculate the value of **x** in $Na_2CO_3.\mathbf{x}H_2O$. Give your answer to the nearest whole number.
[$A_r$: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

**x** = ......................
[6]

**(d) (i)** State the maximum error in any single reading of the burette.

maximum error = .................. $cm^3$

**(ii)** Calculate the maximum percentage error in the volume of **FA 2** in your **first** accurate titre.

maximum percentage error = .......................%
[1]

[Total: 15]

**2** In this experiment you will determine the enthalpy change, $\Delta H$, for the dehydration of hydrated sodium carbonate to anhydrous sodium carbonate.

$$Na_2CO_3.\mathbf{x}H_2O(s) \rightarrow Na_2CO_3(s) + \mathbf{x}H_2O(l)$$

In order to do this, first you will determine the enthalpy changes for the reactions of anhydrous sodium carbonate and hydrated sodium carbonate with excess hydrochloric acid. Then you will use Hess' Law to calculate the enthalpy change for the reaction above.

**FA 4** is anhydrous sodium carbonate, $Na_2CO_3$.
**FA 5** is hydrated sodium carbonate, $Na_2CO_3.\mathbf{x}H_2O$.
**FA 6** is 4.0 mol $dm^{-3}$ hydrochloric acid, HC*l*.

**(a)** Determination of the enthalpy change for the reaction of anhydrous sodium carbonate, **FA 4**, with excess hydrochloric acid.

**Method**

- Support a plastic cup in the 250 $cm^3$ beaker.
- Use the measuring cylinder to transfer 25 $cm^3$ of **FA 6** into the plastic cup.
- Record the initial temperature of the acid.
- Weigh the container with **FA 4** and record the mass.
- **Slowly** add all the **FA 4** to the acid in the plastic cup.
  Note that the reaction will be vigorous. Avoid inhaling any acid spray produced.
- Stir constantly until the maximum temperature is reached.
  Record the maximum temperature.
- Weigh the container from which you added **FA 4** and record the mass.
- Calculate and record the mass of **FA 4** used and the temperature rise.

[3]

**(b) Calculation**

**(i)** Calculate the energy produced during this reaction.
[Assume that 4.2 J are needed to raise the temperature of 1.0 $cm^3$ of solution by 1.0 °C.]

energy produced = ........................ J

**(ii)** Calculate the number of moles of anhydrous sodium carbonate used.
[$A_r$: C, 12.0; O, 16.0; Na, 23.0]

moles of $Na_2CO_3$ = .................... mol

**(iii)** Calculate the enthalpy change, in kJ $mol^{-1}$, for the reaction below.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

enthalpy change for anhydrous $Na_2CO_3$ = ........... *sign* ............... *value* kJ $mol^{-1}$

[3]

**(c)** Determination of the enthalpy change for the reaction of hydrated sodium carbonate, **FA 5**, with excess hydrochloric acid.

**Method**

- Support the second plastic cup in the 250 $cm^3$ beaker.
- Use the measuring cylinder to transfer 25 $cm^3$ of **FA 6** into the plastic cup.
- Record the initial temperature of the acid.
- Weigh the container with **FA 5** and record the mass.
- Slowly add all the **FA 5** to the acid in the plastic cup.
  Note that the reaction will be vigorous. Avoid inhaling any acid spray produced.
- Stir constantly until the minimum temperature is reached.
  Record the minimum temperature.
- Weigh the container from which you added **FA 5** and record the mass.
- Calculate and record the mass of **FA 5** used and the temperature decrease.

[2]

**(d) Calculation**

**(i)** Calculate the energy absorbed during this reaction.
[Assume that 4.2 J are absorbed when the temperature of 1.0 $cm^3$ of solution falls by 1.0 °C.]

energy absorbed = ......................... J

**(ii)** Use your answer to **1(c)(vi)** to calculate the number of moles of hydrated sodium carbonate, $Na_2CO_3.\mathbf{x}H_2O$, used.
[$A_r$: H, 1.0; C, 12.0; O, 16.0; Na, 23.0]

(If you were unable to calculate **x** in **1(c)(vi)**, you may assume that **x** = 8. Note: this is not the correct value.)

moles of $Na_2CO_3.\mathbf{x}H_2O$ = .................... mol

**(iii)** Calculate the enthalpy change, in $kJ\,mol^{-1}$, for the reaction below.

$$Na_2CO_3.\mathbf{x}H_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + (\mathbf{x} + 1)H_2O(l)$$

enthalpy change for $Na_2CO_3.\mathbf{x}H_2O$ = .......... .............. $kJ\,mol^{-1}$
*sign* *value*

[2]

**(e)** Use your values for the enthalpy changes calculated in **(b)(iii)** and **(d)(iii)** to calculate the enthalpy change for the reaction below.

$$Na_2CO_3.\mathbf{x}H_2O(s) \rightarrow Na_2CO_3(s) + \mathbf{x}H_2O(l)$$

Show clearly how you obtained your answer.

(If you were unable to calculate the enthalpy changes, you should assume that the value in **(b)(iii)** is $-43.1\,kJ\,mol^{-1}$ and the value in **(d)(iii)** is $+32.8\,kJ\,mol^{-1}$. Note: these are not the correct values.)

enthalpy change = .......... .............. $kJ\,mol^{-1}$
*sign* *value*

[2]

**(f)** A student suggested that the experiments carried out in **(a)** and **(c)** would be more accurate if double the volume of hydrochloric acid had been used, but with hydrochloric acid of concentration $2.0\,mol\,dm^{-3}$, instead of $4.0\,mol\,dm^{-3}$.
State and explain whether or not you agree with the student's suggestion.

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.......................................................................................................................................... [1]

[Total: 13]

**3 Qualitative Analysis**

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 precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
**No additional tests for ions present should be attempted.**

**If any solution is warmed, a boiling tube MUST be used.**

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

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

**(a)** **FA 7** and **FA 8** are mixtures. Each mixture contains one cation and two anions from those listed on pages 12 and 13.
Carry out the following tests and record all your observations in the table below.

| *test* | *observations* | |
|---|---|---|
| | **FA 7** | **FA 8** |
| **(i)** Place a spatula measure of **FA 7** or **FA 8** into a boiling tube, then add approximately 5 $cm^3$ of dilute nitric acid using the measuring cylinder. (Do **not** use **FA 2** as the dilute nitric acid.) Then | | |
| add about 5 $cm^3$ of distilled water and shake to mix the solution. Use a 1 cm depth of the solution obtained in a test-tube for each of tests **(ii)** – **(v)**. | No observation required. | |
| **(ii)** Add aqueous sodium hydroxide. | | Do not carry out this test. |
| **(iii)** Add aqueous ammonia. | | Do not carry out this test. |
| **(iv)** Add aqueous barium nitrate followed by dilute nitric acid. | | |
| **(v)** Add aqueous silver nitrate followed by aqueous ammonia. | | |

**(vi)** Use your observations to identify the following ions.

**FA 7** contains cation ..........................................

**FA 7** contains anions .......................................... and ..................................................

**FA 8** contains anions .......................................... and ..................................................

State and explain **all** the evidence for your identification of the cation in **FA 7**.

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[7]

**(b)** **FA 9** contains two cations from the list on page 12.

**(i)** Transfer approximately half of the **FA 9** into a hard-glass test-tube and heat gently at first, and then strongly, until no further change is seen.
Test with litmus papers while you are heating.
Record all your observations below.

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**(ii)** Carry out further tests that will enable you to identify **both** cations in **FA 9**.
Describe your tests briefly and state your observations.

**FA 9** contains cations .......................................... and ......................................................
[5]

[Total: 12]

## Qualitative Analysis Notes

*Key: [ppt. = precipitate]*

### 1 Reactions of aqueous cations

| *ion* | *reaction with* | |
|---|---|---|
| | NaOH(aq) | $NH_3$(aq) |
| aluminium,<br>$Al^{3+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>insoluble in excess |
| ammonium,<br>$NH_4^+$(aq) | no ppt.<br>ammonia produced on heating | – |
| barium,<br>$Ba^{2+}$(aq) | no ppt. (if reagents are pure) | no ppt. |
| calcium,<br>$Ca^{2+}$(aq) | white ppt. with high [$Ca^{2+}$(aq)] | no ppt. |
| chromium(III),<br>$Cr^{3+}$(aq) | grey-green ppt. soluble in excess giving dark green solution | grey-green ppt.<br>insoluble in excess |
| copper(II),<br>$Cu^{2+}$(aq) | pale blue ppt.<br>insoluble in excess | blue ppt. soluble in excess giving dark blue solution |
| iron(II),<br>$Fe^{2+}$(aq) | green ppt. turning brown on contact with air<br>insoluble in excess | green ppt. turning brown on contact with air<br>insoluble in excess |
| iron(III),<br>$Fe^{3+}$(aq) | red-brown ppt.<br>insoluble in excess | red-brown ppt.<br>insoluble in excess |
| magnesium,<br>$Mg^{2+}$(aq) | white ppt.<br>insoluble in excess | white ppt.<br>insoluble in excess |
| manganese(II),<br>$Mn^{2+}$(aq) | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>insoluble in excess |
| zinc,<br>$Zn^{2+}$(aq) | white ppt.<br>soluble in excess | white ppt.<br>soluble in excess |

 

## 2 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 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;<br>NO liberated by dilute acids<br>(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;<br>gives white ppt. with $Ba^{2+}(aq)$ (soluble in excess dilute strong acids) |

## 3 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<br>(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 acidified aqueous potassium manganate(VII) from purple to colourless |

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