UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

5803539249

CHEMISTRY **9701/35**

Paper 31 Advanced Practical Skills **May/June 2010**

2 hours

Candidates answer on the Question Paper.

Additional Materials: As listed in the Instructions to Supervisors

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
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 14 and 15.

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	
Total	

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

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1 You are required to find the molar enthalpy change for the decomposition of sodium hydrogencarbonate, $NaHCO_3$.

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$$NaHCO_3 \rightarrow \tfrac{1}{2}Na_2CO_3 + \tfrac{1}{2}H_2O + \tfrac{1}{2}CO_2$$

FA 1 is anhydrous sodium hydrogencarbonate. **FA 2** is anhydrous sodium carbonate.
FA 3 is 4.0 mol dm^{-3} hydrochloric acid.

You will determine the value for the molar enthalpy change of neutralisation for each of **FA 1** and **FA 2**, using an excess of **FA 3**. You will then use these values to calculate the molar enthalpy change for the decomposition of sodium hydrogencarbonate.

Warning: 4.0 mol dm^{-3} hydrochloric acid is an **irritant**.
Very rapid effervescence occurs when FA 1 or FA 2 are added to FA 3. For safe working, and to minimize the formation of 'acid mist', the solid must be added **carefully**, with stirring, to the acid. See further instructions below.

Before starting any practical work read through the instructions in (a) and draw up two tables to record your results.

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(a) Determining the molar enthalpy change of neutralisation between FA 1 and FA 3

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

Follow the instructions below to determine the temperature change when a known mass of **FA 1**, sodium hydrogencarbonate, reacts with an excess of **FA 3**, hydrochloric acid.

- Weigh the stoppered tube labelled **FA 1** containing sodium hydrogencarbonate.
- Use a 50 cm^3 measuring cylinder to transfer 50 cm^3 of **FA 3** into a 250 cm^3 beaker.
- Stir the acid in the beaker with the thermometer. Record the temperature of the acid; this is the temperature at t = 0 min.
- Record the temperature each minute for 3 minutes.
- At t = 4 min, start to **carefully** add the weighed sample of **FA 1** to the acid.
- Add the solid **in at least 4 or 5 portions** to prevent excessive effervescence.
- While adding the solid stir the mixture constantly with the thermometer, but do **not** record the temperature.
- Continue to stir the mixture throughout the experiment.
- Record the temperature at t = 5 min, then every **½ minute** until t = 8 min.
- Reweigh the tube labelled **FA 1**, its stopper and any residual sodium hydrogencarbonate.
- Empty and rinse the beaker and dry it using a paper towel.
- In one of your tables record the balance readings and the mass of **FA 1** added; in the second table record all measurements of time and temperature.

Table of results

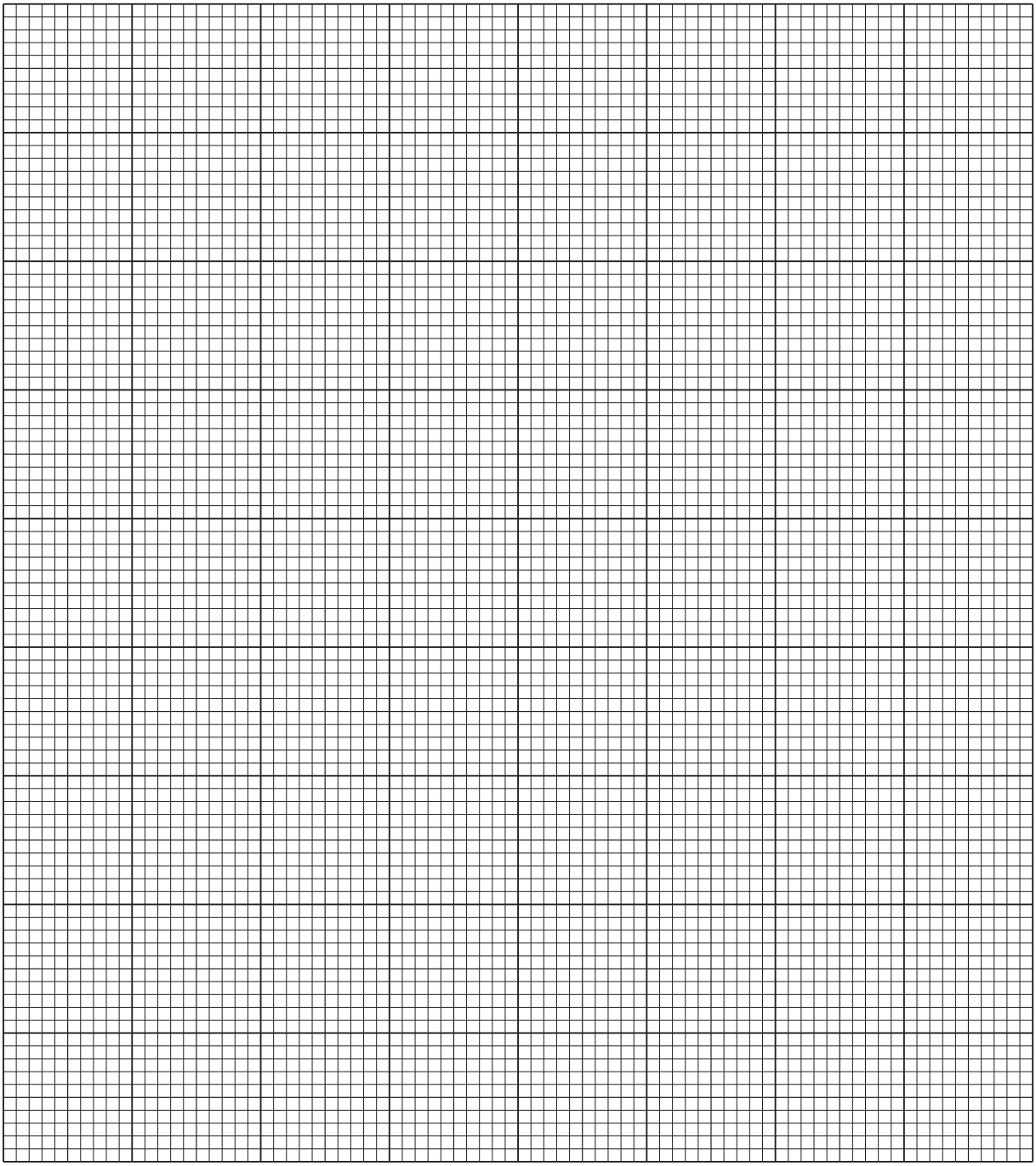
[3]

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(b) Graph plotting

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1. Plot a graph of temperature (y-axis) against time (x-axis) on the grid below.
2. Draw two straight lines of best fit; one through the points up to t = 3 min; the second through the points from t = 5 min to t = 8 min. Extrapolate both lines to t = 4 min.
3. From the extrapolated lines read the minimum and the maximum temperatures at t = 4 min. Record these values in the spaces provided below.
4. Determine the value for the temperature fall at t = 4 min.



The minimum temperature at t = 4 min is ……. °C.

The maximum temperature at t = 4 min is ……. °C.

The temperature fall, ΔT_1, at t = 4 min is ……. °C. [4]

(c) Calculations

For Examiner's Use

Working should be shown in all calculations.

(i) Use the equation below and the temperature fall, ΔT_1, from **(b)** to calculate the change in heat energy during the reaction of **FA 1** with **FA 3**.

$$\text{change in heat energy} = 50 \times 4.3 \times \Delta T_1$$

The change in heat energy = ... J.

(ii) Calculate how many moles of **FA 1**, $NaHCO_3$, were used in your experiment.
[A_r; C, 12.0; H, 1.0; O, 16.0; Na, 23.0]

..... mol of **FA 1** were used in the experiment.

(iii) Calculate the enthalpy change when 1 mol of **FA 1** reacts with an excess of the hydrochloric acid, **FA 3**.
This is the molar enthalpy change of neutralisation, $\Delta H_{\text{neutralisation}}$ ($NaHCO_3$).
Make certain that your answer is given in $kJ\,mol^{-1}$ and has the appropriate sign.

$\Delta H_{\text{neutralisation}}(NaHCO_3)$ = ... $kJ\,mol^{-1}$.
sign *calculated value*

(iv) Explain the significance of the sign you have given in **(iii)** and how it is related to your experimental results.

.....

.....

.....
[3]

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(d) Determining the molar enthalpy change of neutralisation between FA 2 and FA 3

For Examiner's Use

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

Follow the instructions below to find the temperature change when a known mass of **FA 2**, sodium carbonate, reacts with an excess of **FA 3**, hydrochloric acid.

You are provided with two samples of sodium carbonate. You should use the sample labelled **Na_2CO_3** in **experiment 1** and the sample labelled **FA 2** in **experiment 2**.

Experiment 1

- Enter all results in the table below.
- Weigh the stoppered tube containing sodium carbonate, which is labelled **Na_2CO_3**.
- Use a 50 cm^3 measuring cylinder to transfer 50 cm^3 of **FA 3** into the rinsed and dried 250 cm^3 beaker used in **(a)**.
- Stir the acid in the beaker with the thermometer and record the temperature.
- Start to add **carefully** the weighed sample of Na_2CO_3 to the acid.
- As in the experiment in **(a)**, add the solid **in at least 4 or 5 portions** to prevent excessive effervescence.
- While adding the solid stir the mixture constantly with the thermometer.
- Record the maximum temperature obtained during the reaction.
- Reweigh the tube labelled **Na_2CO_3**, its stopper and any residual sodium carbonate.
- Empty and rinse the beaker and dry it using a paper towel.

Experiment 2

- Enter all results in the table below.
- Weigh a clean, dry, boiling-tube.
- Weigh between 7.0 g and 7.5 g of **FA 2**, sodium carbonate, into the boiling-tube.
- Repeat the procedure in **experiment 1** and record the maximum temperature obtained when this mass of **FA 2** reacts with 50 cm^3 of **FA 3**.
- Reweigh the boiling-tube and any residual sodium carbonate.

Results

	experiment 1	experiment 2
mass of tube + anhydrous sodium carbonate / g		
mass of empty tube / g		
mass of tube + residual sodium carbonate / g		
mass of anhydrous sodium carbonate / g		
initial temperature of acid / ^oC		
maximum temperature obtained / ^oC		
temperature rise, ΔT_2 / ^oC		

[6]

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(e) Calculations

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Working should be shown in all calculations.

(i) Use the equation below and the temperature rise, ΔT_2, from **(d)** for **experiment 1** to calculate the change in heat energy during the reaction of sodium carbonate with **FA 3**.

$$\text{change in heat energy} = 50 \times 4.3 \times \Delta T_2$$

Change in heat energy = ... J.

(ii) Calculate how many moles of sodium carbonate were used in your **experiment 1**.
[A_r; C, 12.0; O, 16.0; Na, 23.0]

..... mol of sodium carbonate were used in **experiment 1**.

(iii) Calculate the enthalpy change when 1 mol of sodium carbonate reacts with an excess of the hydrochloric acid, **FA 3**.
This is the molar enthalpy change of reaction, $\Delta H_{\text{neutralisation}}(Na_2CO_3)$.
Make certain that your answer is given in $kJ\,mol^{-1}$ and has the appropriate sign.

$\Delta H_{\text{neutralisation}}(Na_2CO_3)$ = ... $kJ\,mol^{-1}$.
sign *calculated value*

(iv) Explain the significance of the sign you have given in **(iii)** and how it is related to your experimental results.

.....

.....

.....
[5]

For Examiner's Use

(f) Calculating the enthalpy change of decomposition of FA 1, $\Delta H_{decomposition}(NaHCO_3)$

Use your values for $\Delta H_{neutralisation}$ ($NaHCO_3$) and $\Delta H_{neutralisation}$ (Na_2CO_3) in the expression below to calculate a value for the molar enthalpy change of decomposition, $\Delta H_{decomposition}$ ($NaHCO_3$), for **FA 1**.

$$\Delta H_{decomposition}(NaHCO_3) = \Delta H_{neutralisation}(NaHCO_3) - \tfrac{1}{2}\Delta H_{neutralisation}(Na_2CO_3)$$

$\Delta H_{decomposition}(NaHCO_3)$ = ... $kJ\,mol^{-1}$.

sign *calculated value*

[1]

(g) Evaluation

An alternative method for the determination of $\Delta H_{decomposition}$ ($NaHCO_3$) gave a value of $+42.5\,kJ\,mol^{-1}$.
The value you have obtained may be significantly different from this value.

Calculate the difference between your value of $\Delta H_{decomposition}$ ($NaHCO_3$) and that obtained by the alternative method.

Record this difference below. Express this difference as a percentage of the alternative value.

difference = …… $kJ\,mol^{-1}$

percentage difference = …….. %

[1]

(h) Sources of error

Describe **one** major source of error in this experiment. Suggest an improvement which would significantly increase the accuracy of the experiment. Explain why your suggestion would produce a more accurate value.

description of major source of error

.....

.....

suggested improvement

.....

.....

explanation of why suggestion would increase experimental accuracy

.....

.....

[2]

[Total: 25]

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2 **(a)** You are provided with three solutions, **FA 4**, **FA 5** and **FA 6**. The only anions that may be present in these solutions are carbonate and chloride. One or more of the solutions may contain both anions.

Identification of the anions in FA 4, FA 5 and FA 6

Most metal carbonates are insoluble, most metal chlorides are soluble and all metal nitrates are soluble in water.

(i) Use this information and the Qualitative Analysis Notes on page 15 to select
- **reagent 1**, to identify any carbonate ion that is present,
- **reagent 2**, to identify any chloride ion present.

reagent 1 ..... **reagent 2** ..... [1]

(ii) Explain the order in which you will add your chosen reagents to determine the anion or anions present in each of **FA 4**, **FA 5** and **FA 6**.

.....

.....

..... [1]

(iii) Use the reagents selected in **(a)(i)** to test each of the solutions **FA 4**, **FA 5** and **FA 6**. Record your observations in the table below.

reagent	observations		
	FA 4	**FA 5**	**FA 6**

[2]

(iv) From your observations, identify the anion or anions present in each of the solutions.

solution	carbonate	chloride	evidence
FA 4			
FA 5			
FA 6			

[2]

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(b) You are provided with four solutions, **FA 7**, **FA 8**, **FA 9** and **FA 10**. Perform the test-tube experiments described below and record your observations in the table.

tests		observations			
		FA 7	**FA 8**	**FA 9**	**FA 10**
(i)	To about 1 cm depth of solution in a test-tube, add 5 drops of aqueous sodium hydroxide, shake the mixture then,				
	add a further 2 cm depth of aqueous sodium hydroxide.				
(ii)	To about 1 cm depth of solution in a test-tube, add 10 drops of aqueous ammonia, shake the mixture then,				
	add a further 2 cm depth of aqueous ammonia.				
(iii)	Select a reagent that will confirm the identity of any ions producing white precipitates in both of the tests above. To about 1 cm depth of solution in a test-tube add the selected reagent. Record the appropriate observations below.				
	The reagent is				

[7]

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vii	vi	v	iv	iii	ii	i

(c) From your observations, identify the cation present in each of the following solutions.

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solution	cation	evidence
FA 7		
FA 9		
FA 10		

[2]

[Total: 15]

Qualitative Analysis Notes

Key: [ppt. = precipitate.]

1 Reactions of aqueous cations

ion	*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)	no ppt. 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
lead(II), Pb^{2+}(aq)	white ppt. soluble in excess	white 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

[Lead(II) ions can be distinguished from aluminium ions by the insolubility of lead(II) chloride.]

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2 Reactions of anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chromate(VI), CrO_4^{2-} (aq)	yellow solution turns orange with H^+(aq); gives yellow ppt. with Ba^{2+}(aq); gives bright yellow ppt. with Pb^{2+}(aq)
chloride, Cl^- (aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
bromide, Br^- (aq)	gives cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq)); gives white ppt. with Pb^{2+}(aq)
iodide, I^- (aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq)); gives yellow ppt. with Pb^{2+}(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 → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acid) or gives white ppt. with Pb^{2+}(aq)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acid)

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 (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 dichromate(VI) (aq) from orange to green

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