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## 9701/31

**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 10 and 11.

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.

|                   |
|-------------------|
| <b>Session</b>    |
|                   |
| <b>Laboratory</b> |
|                   |

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| 2                  |  |
| Total              |  |

This document consists of **11** printed pages and **1** blank page.

# 1 Read through question 1 before starting any practical work.

For  
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Use

You are provided with the following reagents.

**FA 1**,  $2.0 \text{ mol dm}^{-3}$  sulfuric acid,  $\text{H}_2\text{SO}_4$

**FA 2**, aqueous sodium hydroxide,  $\text{NaOH}$

The reaction of sulfuric acid with sodium hydroxide is exothermic.

In separate experiments you will add increasing volumes of **FA 2** to a fixed volume of **FA 1**. In each experiment you will measure the maximum temperature rise. As the volume of **FA 2** is increased, this maximum temperature rise will increase and then decrease.

By measuring the maximum temperature rise for different mixtures of the two reagents you are to determine the following.

- the concentration of sodium hydroxide,  $\text{NaOH}$ , in **FA 2**
- the enthalpy change when 1 mol of  $\text{H}_2\text{SO}_4$  is neutralised by  $\text{NaOH}$

## (a) Method

- Fill the burette with **FA 1**.
- Support the plastic cup in the  $250 \text{ cm}^3$  beaker.
- Run  $10.00 \text{ cm}^3$  of **FA 1** from the burette into the plastic cup.
- Measure  $10 \text{ cm}^3$  of **FA 2** in a measuring cylinder.
- Place the thermometer in the **FA 2** in the measuring cylinder and record the steady temperature of the solution.
- Tip the **FA 2** in the measuring cylinder into the plastic cup, stir and record the maximum temperature obtained in the reaction.
- Empty and rinse the plastic cup. Rinse the thermometer. Shake dry the plastic cup.
- Carry out the experiment four more times. Each time use  $10.00 \text{ cm}^3$  of **FA 1**. Use  $20 \text{ cm}^3$ ,  $30 \text{ cm}^3$ ,  $40 \text{ cm}^3$  and  $50 \text{ cm}^3$  of **FA 2** in these different experiments.

Carry out **two further experiments**.

Choose volumes of **FA 2** which will allow you to investigate more precisely the volume of **FA 2** that produces the highest temperature rise when added to  $10.00 \text{ cm}^3$  of **FA 1**.

## Results

Record your results in an appropriate form showing, for each experiment, the volumes of solution used, temperature measurements and the temperature rise.

|      |  |
|------|--|
| i    |  |
| ii   |  |
| iii  |  |
| iv   |  |
| v    |  |
| vi   |  |
| vii  |  |
| viii |  |
| ix   |  |

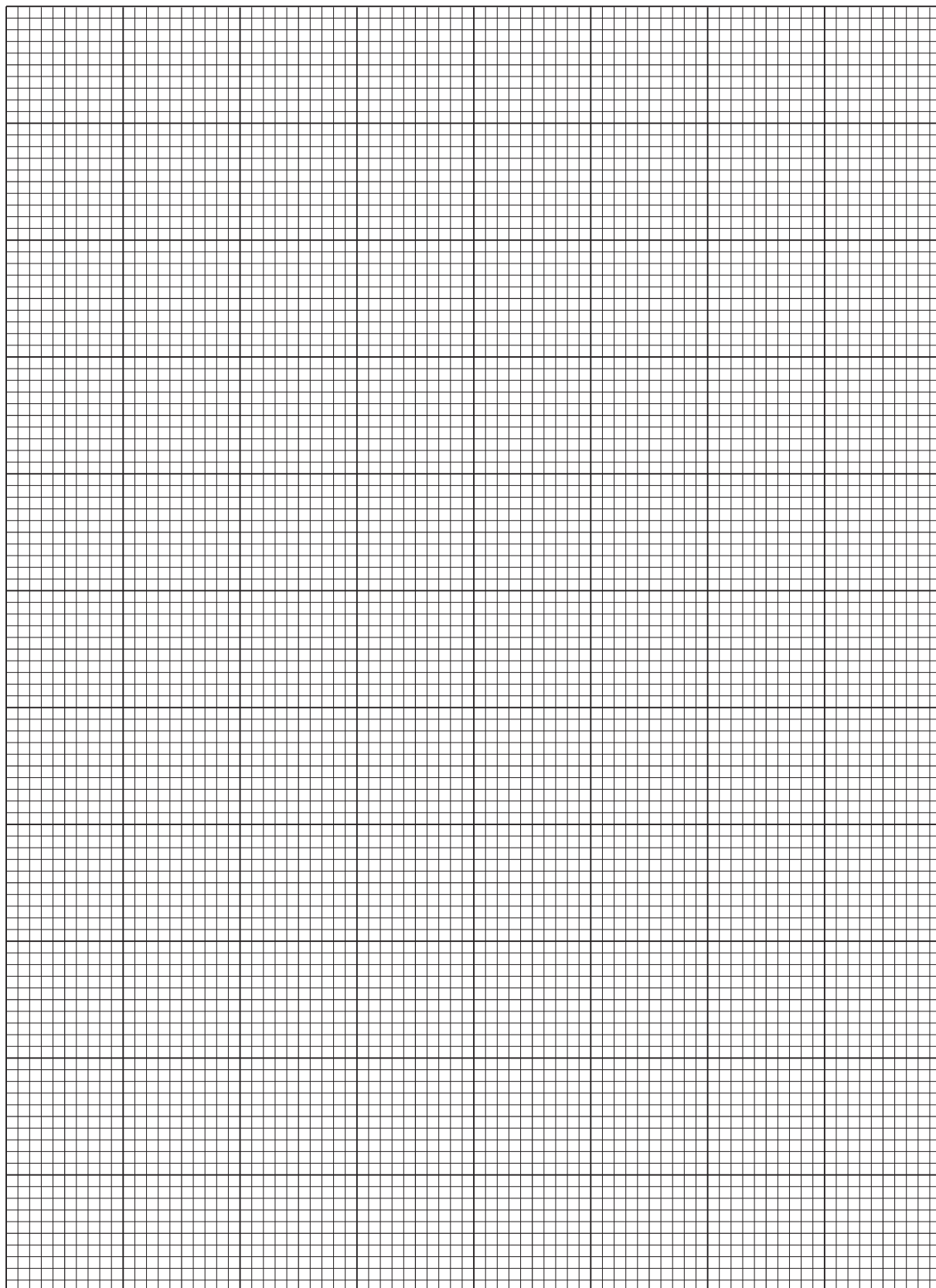
[9]

- (b) Use the grid below to plot a graph of temperature rise (*y-axis*) against the volume of **FA 2** added (*x-axis*).

Draw a line of best fit through the points where the temperature rise is increasing and another line through the points where the temperature rise is decreasing.

The intersection of these lines represents the temperature rise for the volume of **FA 2** that exactly neutralises the sulfuric acid present in  $10.00\text{ cm}^3$  of **FA 1**.

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Use



|     |  |
|-----|--|
| i   |  |
| ii  |  |
| iii |  |
| iv  |  |

[4]

- (c) Read from the graph the volume of **FA 2** that gives the maximum temperature rise.

The volume of **FA 2** giving the maximum temperature rise is .....cm<sup>3</sup>. [1]

- (d) Explain why the temperature rise is plotted on the *y-axis* rather than on the *x-axis*.

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

- (e) Construct the balanced equation for the reaction of sulfuric acid with sodium hydroxide.

..... [1]

- (f) (i) Calculate how many moles of sulfuric acid, H<sub>2</sub>SO<sub>4</sub>, are contained in 10.00cm<sup>3</sup> of **FA 1**.

10.00cm<sup>3</sup> of **FA 1** contain ..... mol of H<sub>2</sub>SO<sub>4</sub>.

- (ii) Calculate how many moles of NaOH are required to neutralise the amount of H<sub>2</sub>SO<sub>4</sub> calculated in (i) above.

The sulfuric acid in 10.00cm<sup>3</sup> of **FA 1** is neutralised by ..... mol of NaOH. [2]

- (g) Use the equation below to calculate the concentration of NaOH in **FA 2**.

$$\text{concentration of NaOH (mol dm}^{-3}\text{)} = \text{answer to (f)(ii)} \times \frac{1000}{\text{volume of FA 2 (cm}^3\text{) from (c)}}$$

The concentration of NaOH in **FA 2** = .....mol dm<sup>-3</sup>. [1]

- (h) Read the maximum temperature rise from the graph and use this to calculate the enthalpy change when 1 mol H<sub>2</sub>SO<sub>4</sub> is neutralised by NaOH. Give your answer in kJ mol<sup>-1</sup> and include the correct sign for the reaction.

[4.3J are absorbed or released when the temperature of 1 cm<sup>3</sup> of solution changes by 1 °C. Remember that separate volumes of **FA 1** and **FA 2** were mixed together.]

$\Delta H =$  ..... kJ mol<sup>-1</sup>. [2]

- (i) A student suggested that the accuracy of the experiment would be improved if the volume of **FA 2** had been measured using a burette rather than a measuring cylinder. Suggest an advantage **and** a disadvantage of using a burette in the procedure.

advantage .....

.....

disadvantage .....

.....

[2]

- (j) Identify **two** further significant sources of error, other than the measurement of volume, in the experiments used for measuring temperature rise.

error 1 .....

.....

error 2 .....

.....

[1]

- (k) Complete the sections below.

(i) The maximum error in taking a temperature reading on a thermometer with graduations at  $1^{\circ}\text{C}$  is ..... $^{\circ}\text{C}$ .

(ii) The temperature rise when  $30\text{cm}^3$  of **FA 2** is added to  $10.00\text{cm}^3$  of **FA 1** is ..... $^{\circ}\text{C}$ .

(iii) Calculate the maximum percentage error due to the thermometer when measuring the temperature **rise** in (ii) above.

The maximum percentage error = ..... %.

[2]

[Total: 26]

- 2 Solutions **FA 3**, **FA 4** and **FA 5** each contain a Group 2 halide.  
Solution **FA 6** contains a potassium salt.

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You will carry out tests to deduce the following.

- the anion present in **FA 6**
- the solution containing the chloride ions
- the solution containing barium ions

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate and the colour of the precipitate

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 directly with a Bunsen burner a boiling-tube MUST be used.**

Rinse and reuse test-tubes where possible.

- (a) Use information from the Qualitative Analysis Notes on page 11 to select a pair of reagents that, **used together**, identify the halide ion present.

The reagents are .....

followed by ..... .

[1]

- (b) Use your chosen reagents to carry out tests on **FA 3**, **FA 4** and **FA 5**.  
Record your results in an appropriate form in the space below.

[2]

- (c) From the results of the tests in (b) state which solution contains the chloride ion,  $Cl^-$ .

Solution ..... contains the chloride ion.

Explain the evidence that supports your conclusion.

.....

..... [1]

- (d) Carry out the following tests on each of the solutions **FA 3**, **FA 4** and **FA 5**.  
Record your observations below.

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| <i>test</i>                                                                           | <i>observations</i> |             |             |
|---------------------------------------------------------------------------------------|---------------------|-------------|-------------|
|                                                                                       | <b>FA 3</b>         | <b>FA 4</b> | <b>FA 5</b> |
| To 1 cm depth of solution in a test-tube, add 2 cm depth of aqueous sodium hydroxide. |                     |             |             |
| To 1 cm depth of solution in a test-tube, add 2 cm depth of aqueous ammonia.          |                     |             |             |
| To 1 cm depth of solution in a test-tube, add 1 cm depth of <b>FA 6</b> .             |                     |             |             |

[3]

- (e) To 1 cm depth of **FA 6** in a test-tube add 1 cm depth of dilute sulfuric acid.

observation

.....

.....[1]

- (f) From your observations in (d) and (e) you should be able to identify the anion in **FA 6** and which of the solutions **FA 3**, **FA 4** or **FA 5** contains barium cations.

The anion present in **FA 6** is .....

$\text{Ba}^{2+}$  ions are contained in solution .....

Explain how your observations support your conclusions for

- (i) the anion present in **FA 6**, .....

.....

- (ii) the solution containing  $\text{Ba}^{2+}$  ions. ....

.....

[1]

**Read through the remainder of question 2 before starting further practical work.**

**Heat a half-full 250 cm<sup>3</sup> beaker of water for use as a hot water-bath.**

- (g) **FA 7**, **FA 8**, **FA 9** and **FA 10** are organic compounds. Each contains one of the following different functional groups.

- primary alcohol
- tertiary alcohol
- aldehyde
- ketone

You are to react some of these compounds with some of the following reagents.

- acidified aqueous potassium dichromate(VI)
- 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent
- ammoniacal silver nitrate (Tollens' reagent)

You are provided with the first two reagents. You must prepare the last of these reagents, Tollens' reagent, immediately before use. Follow the instructions in the box below.

To 2 cm depth of aqueous silver nitrate in a boiling-tube add ½ cm depth of aqueous sodium hydroxide. This will produce a brown precipitate of silver(I) oxide. Add aqueous ammonia a little at a time, with continuous shaking, until the brown precipitate **just** dissolves. **Do not add an excess of aqueous ammonia.**

In each of the following tests add a few drops of the reagent to 1 cm depth of **FA 7**, **FA 8**, **FA 9** and **FA 10** in separate test-tubes.

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In the tests using acidified potassium dichromate(VI) and Tollens' reagent, if no initial reaction is seen, warm that tube and its contents in your hot water-bath. There is no need to heat any tube to which you have added 2,4-DNPH reagent.

Do **not** heat any tube with a naked flame.

Record your results in the table below.

Do **not** carry out tests for the shaded boxes.

| reagent                            | observations |      |      |       |
|------------------------------------|--------------|------|------|-------|
|                                    | FA 7         | FA 8 | FA 9 | FA 10 |
| acidified potassium dichromate(VI) |              |      |      |       |
| 2,4-DNPH reagent                   |              |      |      |       |
| Tollens' reagent                   |              |      |      |       |

[3]

- (h) State which of the solutions contains a tertiary alcohol. Explain the observations leading to your conclusion.

**FA** ..... contains the tertiary alcohol.

explanation .....

.....

State which of the solutions contains the aldehyde. Explain the observations leading to your conclusion.

**FA** ..... contains the aldehyde.

explanation .....

.....

[2]

[Total: 14]

Key: [ ppt. = precipitate. ]

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | —                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | no ppt. (if reagents are pure)                                                     | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt. soluble in excess<br>giving dark green solution                    | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | blue ppt. soluble in excess<br>giving dark blue solution                           |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| lead(II),<br>Pb <sup>2+</sup> (aq)             | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

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

## 2 Reactions of anions

| <i>ion</i>                                      | <i>reaction</i>                                                                                                                                                                                           |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$                | $\text{CO}_2$ liberated by dilute acids                                                                                                                                                                   |
| chromate(VI),<br>$\text{CrO}_4^{2-}(\text{aq})$ | yellow solution turns orange with $\text{H}^+(\text{aq})$ ;<br>gives yellow ppt. with $\text{Ba}^{2+}(\text{aq})$ ;<br>gives bright yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                          |
| chloride,<br>$\text{Cl}^-(\text{aq})$           | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                               |
| bromide,<br>$\text{Br}^-(\text{aq})$            | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                     |
| iodide,<br>$\text{I}^-(\text{aq})$              | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ );<br>gives yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                                                           |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil                                                                                                                     |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil;<br>$\text{NO}$ liberated by dilute acids<br>(colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ in air) |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$       | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ or with $\text{Pb}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids);                                                                          |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$       | $\text{SO}_2$ liberated with dilute acids;<br>gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)                                                                   |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                      |
|-------------------------------|----------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                                 |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater<br>(ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                       |
| hydrogen, $\text{H}_2$        | "pops" with a lighted splint                                                     |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                        |
| sulfur dioxide, $\text{SO}_2$ | turns acidified aqueous potassium dichromate(VI) from orange to green            |

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**CHEMISTRY**

Paper 31 Advanced Practical Skills

**9701/33**

**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 15 and 16.

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    |
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|            |
| Laboratory |
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- 1 You are required to determine the molar enthalpy change of solution for ammonium chloride, **FA 1**.

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When an exothermic reaction takes place in a container such as a beaker, some of the evolved heat energy is absorbed by the beaker.

When an endothermic reaction takes place some of the required heat energy is supplied by the beaker.

The amount of heat energy evolved or supplied for a 1 °C change in temperature is known as the heat capacity of the beaker.

In preparation for your experiment to determine the molar enthalpy change of solution for **FA 1** you will first need to determine the approximate heat capacity of a 250 cm<sup>3</sup> beaker.

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

**(a) Determining the approximate heat capacity of the 250 cm<sup>3</sup> beaker**

When samples of hot and cold water are mixed in the 250 cm<sup>3</sup> beaker, some heat is lost to the beaker in raising its temperature. To determine the approximate heat capacity of your 250 cm<sup>3</sup> beaker, you will determine the maximum temperature rise when a sample of hot water is added to cold water in the beaker.

- Use a 50 cm<sup>3</sup> measuring cylinder to transfer 50 cm<sup>3</sup> of cold water into the 250 cm<sup>3</sup> beaker.
- Use the 50 cm<sup>3</sup> measuring cylinder to transfer 50 cm<sup>3</sup> of cold water into a 100 cm<sup>3</sup> beaker. Note the temperature of the water in this 100 cm<sup>3</sup> beaker and heat it **carefully and gently** until the temperature of the water in it has increased by 45–50 °C then stop heating, *e.g. if the water is at 20.0 °C you should warm it to 65–70 °C*.
- Stir the cold water in the 250 cm<sup>3</sup> beaker with the thermometer.
- Record the temperature of the cold water (this is the temperature at  $t = 0$  min).
- Record the temperature each minute for 3 minutes.
- After you have taken the reading at  $t = 3$  min, use the thermometer to stir the hot water in the 100 cm<sup>3</sup> beaker.
- At  $t = 4$  min, measure the temperature of the hot water and record this value in the box below.
- **Immediately** add the hot water from the 100 cm<sup>3</sup> beaker to the cold water in the 250 cm<sup>3</sup> beaker. Stir with the thermometer but do **not** record the temperature.
- Continue to stir the water throughout the experiment.
- Record the temperature at  $t = 5$  min, and then every ½ **minute** until  $t = 8$  min.
- Empty and rinse the 250 cm<sup>3</sup> beaker. Dry it using a paper towel.
- Record all measurements of time and temperature obtained.

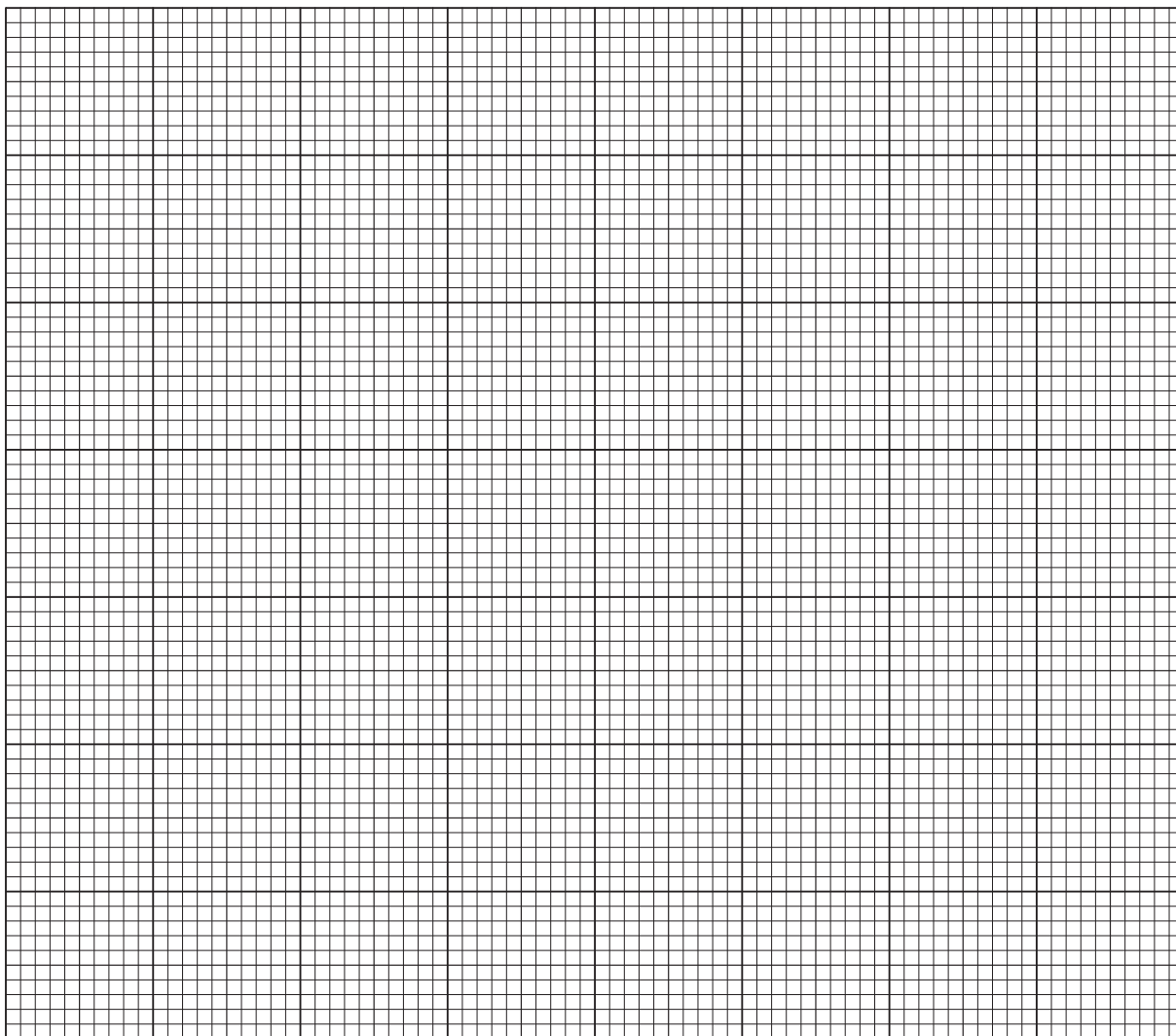
The temperature,  $T_1$ , of the hot water at  $t = 4$  min is ..... °C.

**Table of results**

[3]

**(b) Graph plotting**

1. Plot a graph of the temperature of the water in the 250 cm<sup>3</sup> beaker (y-axis) against time (x-axis) on the grid below.  
Do **not** plot the temperature,  $T_1$ , of the hot water at  $t = 4$  min.
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 values for the two temperature changes at  $t = 4$  min.



Minimum temperature,  $T_2$ , at  $t = 4$  min is ..... °C.

Maximum temperature,  $T_3$ , at  $t = 4$  min is ..... °C.

Temperature rise for 50 cm<sup>3</sup> of cold water in the 250 cm<sup>3</sup> beaker,  $(T_3 - T_2)$  is ..... °C.

Temperature fall for 50 cm<sup>3</sup> of hot water from the 100 cm<sup>3</sup> beaker,  $(T_1 - T_3)$  is ..... °C.  
[4]

**(c) Calculations**For  
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Working should be shown in all calculations.

[**4.2 J** are absorbed or released when the temperature of  $1.0\text{ cm}^3$  of **water** changes by  $1.0^\circ\text{C}$ .]

- (i) Calculate the heat energy gained by the  $50\text{ cm}^3$  of cold water in the  $250\text{ cm}^3$  beaker.

The heat energy gained by the cold water = ..... J.

- (ii) Calculate the heat energy lost by the  $50\text{ cm}^3$  of hot water from the  $100\text{ cm}^3$  beaker.

The heat energy lost by the hot water = ..... J.

- (iii) The difference between the values calculated in (i) and (ii) is an approximate value for the total heat energy absorbed by the  $250\text{ cm}^3$  beaker during the experiment. The heat capacity of the beaker is the amount of heat energy absorbed for a  $1^\circ\text{C}$  change in temperature.

$$\text{approximate heat capacity of the } 250\text{ cm}^3 \text{ beaker} = \frac{(\text{heat energy lost}) - (\text{heat energy gained})}{(T_3 - T_2)} \text{ J}^\circ\text{C}^{-1}$$

Use your answers to (i) and (ii) and the temperature rise from (b) to calculate the approximate heat capacity of the  $250\text{ cm}^3$  beaker.

The approximate heat capacity of the  $250\text{ cm}^3$  beaker = .....  $\text{J}^\circ\text{C}^{-1}$ .

[1]

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**(d) Determining the enthalpy change of solution for ammonium chloride**For  
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Follow the instructions below to find the temperature change when a known mass of solid ammonium chloride dissolves in water.

You are provided with two samples of ammonium chloride. You should use the sample labelled **NH<sub>4</sub>Cl** in **experiment 1** and the sample labelled **FA 1** in **experiment 2**.

**Experiment 1**

- Enter all results in the table below.
- Weigh the stoppered tube containing ammonium chloride, which is labelled **NH<sub>4</sub>Cl**.
- Use the 50 cm<sup>3</sup> measuring cylinder to transfer 100 cm<sup>3</sup> of cold water into the rinsed and dried 250 cm<sup>3</sup> beaker used in **(a)**.
- Stir the water in the beaker with the thermometer and record the temperature.
- Add the solid from the weighed tube to the water.
- Stir the mixture constantly with the thermometer.
- Record the minimum temperature obtained in the solution.
- Reweigh the tube labelled **NH<sub>4</sub>Cl**, its stopper and any residual ammonium chloride.
- 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 9.8 g and 10.2 g of **FA 1**, ammonium chloride, into the boiling-tube.
- Repeat the procedure in **experiment 1** and record the minimum temperature obtained when this mass of **FA 1** dissolves in 100 cm<sup>3</sup> of water.
- Reweigh the boiling-tube and any residual ammonium chloride.

**Results**

|                                               | experiment 1 | experiment 2 |
|-----------------------------------------------|--------------|--------------|
| mass of tube + ammonium chloride / g          |              |              |
| mass of empty tube / g                        |              |              |
| mass of tube + residual ammonium chloride / g |              |              |
| mass of ammonium chloride / g                 |              |              |
| initial temperature of water / °C             |              |              |
| minimum temperature obtained / °C             |              |              |
| temperature fall, $\Delta T$ / °C             |              |              |

[6]

**(e) Calculations**For  
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Use

Working should be shown in all calculations.

- (i) Use the temperature fall from **(d)**, **experiment 1**, to calculate the change in heat energy of the solution.  
[**4.3 J** are absorbed or released when the temperature of  $1.0\text{cm}^3$  of **solution** changes by  $1.0^\circ\text{C}$ .]

The change in heat energy of the solution = ..... J.

- (ii) To calculate the total change in heat energy as ammonium chloride dissolves in water, the change in heat energy of the  $250\text{cm}^3$  beaker has to be added to the change in heat energy of the solution.  
Explain why these two changes in heat energy have to be added together.

.....  
 .....  
 .....

- (iii) Use your answer in **(i)** above and the approximate heat capacity of the  $250\text{cm}^3$  beaker calculated in **(c)(iii)** to calculate the combined change in heat energy of the beaker and solution.

The combined change in heat energy of the beaker and solution = ..... J.

- (iv) Calculate how many moles of **FA 1**,  $\text{NH}_4\text{Cl}$ , were used in **(d)**, **experiment 1**.  
[ $A_r$ : Cl, 35.5; H, 1.0; N, 14.0]

|     |  |
|-----|--|
| i   |  |
| ii  |  |
| iii |  |
| iv  |  |

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

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

.....

.....

.....

[8]

|             |  |
|-------------|--|
| <b>v</b>    |  |
| <b>vi</b>   |  |
| <b>vii</b>  |  |
| <b>viii</b> |  |

**(f) Evaluation**

A data book value for the molar enthalpy change of solution,  $\Delta H_{\text{solution}} (\text{NH}_4\text{Cl})$ , is  $+15.2 \text{ kJ mol}^{-1}$ .

The value you have obtained may be significantly different from this value.

Calculate the difference between your value of  $\Delta H_{\text{solution}} (\text{NH}_4\text{Cl})$  and the data book value. Record this difference below. Express this difference as a percentage of the data book value.

difference = .....  $\text{kJ mol}^{-1}$

percentage difference = ..... %  
[1]

**(g) 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]

- 2 (a) You are provided with three solutions, **FA 2**, **FA 3** and **FA 4**. The only anions that may be present in these solutions are sulfate and carbonate. One or more of the solutions may contain both anions.

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**Identification of the anions in FA 2, FA 3 and FA 4.**

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

- (i) Use this information and the Qualitative Analysis Notes on page 16 to select
- **reagent 1**, to identify any carbonate ion present,
  - **reagent 2**, to identify any sulfate 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 2**, **FA 3** and **FA 4**.

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

- (iii) Use the reagents selected in (a)(i) to test each of the solutions **FA 2**, **FA 3** and **FA 4**. Record your observations in the table below.

| reagent | observations |             |             |
|---------|--------------|-------------|-------------|
|         | <b>FA 2</b>  | <b>FA 3</b> | <b>FA 4</b> |
|         |              |             |             |
|         |              |             |             |

[2]

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

| solution    | carbonate | sulfate | evidence |
|-------------|-----------|---------|----------|
| <b>FA 2</b> |           |         |          |
| <b>FA 3</b> |           |         |          |
| <b>FA 4</b> |           |         |          |

[2]

**(b)** You are provided with four solutions, **FA 5**, **FA 6**, **FA 7** and **FA 8**. Perform the test-tube experiments described below and record your observations in the table. Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

|              | tests                                                                                                                                                                                                                                                      | observations |      |      |      |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|------|------|------|
|              |                                                                                                                                                                                                                                                            | FA 5         | FA 6 | FA 7 | FA 8 |
| <b>(i)</b>   | To about 1 cm depth of solution in a test-tube, add 10 drops of aqueous sodium hydroxide. Shake the mixture,                                                                                                                                               |              |      |      |      |
|              | then add a further 2 cm depth of aqueous sodium hydroxide. Shake the mixture again,                                                                                                                                                                        |              |      |      |      |
|              | then leave the tube to stand for 2–3 minutes.                                                                                                                                                                                                              |              |      |      |      |
| <b>(ii)</b>  | If no precipitate has formed in test <b>(i)</b> above; transfer the solution to a <b>boiling-tube</b> and warm gently with a Bunsen burner.<br><b>Care: heating aqueous sodium hydroxide in a tube may cause the solution to be ejected from the tube.</b> |              |      |      |      |
| <b>(iii)</b> | 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. Shake the mixture again,                                                                                                                                                                                 |              |      |      |      |
|              | then leave the tube to stand for 2–3 minutes.                                                                                                                                                                                                              |              |      |      |      |

[7]

For  
Examiner's  
Use

|     |  |
|-----|--|
| i   |  |
| ii  |  |
| iii |  |
| iv  |  |
| v   |  |
| vi  |  |
| vii |  |

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

*For  
Examiner's  
Use*

| solution | cation | evidence |
|----------|--------|----------|
| FA 5     |        |          |
| FA 6     |        |          |
| FA 8     |        |          |

[2]

[Total: 15]

## Qualitative Analysis Notes

Key: [ ppt. = precipitate. ]

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | —                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | no ppt. (if reagents are pure)                                                     | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt. soluble in excess<br>giving dark green solution                    | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | blue ppt. soluble in excess<br>giving dark blue solution                           |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| lead(II),<br>Pb <sup>2+</sup> (aq)             | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

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

## 2 Reactions of anions

| <i>ion</i>                                      | <i>reaction</i>                                                                                                                                                                                           |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$                | $\text{CO}_2$ liberated by dilute acids                                                                                                                                                                   |
| chromate(VI),<br>$\text{CrO}_4^{2-}(\text{aq})$ | yellow solution turns orange with $\text{H}^+(\text{aq})$ ;<br>gives yellow ppt. with $\text{Ba}^{2+}(\text{aq})$ ;<br>gives bright yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                          |
| chloride,<br>$\text{Cl}^-(\text{aq})$           | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                               |
| bromide,<br>$\text{Br}^-(\text{aq})$            | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                     |
| iodide,<br>$\text{I}^-(\text{aq})$              | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ );<br>gives yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                                                           |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil                                                                                                                     |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil;<br>$\text{NO}$ liberated by dilute acids<br>(colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ in air) |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$       | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acid) or<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                        |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$       | $\text{SO}_2$ liberated with dilute acids;<br>gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acid)                                                                    |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                      |
|-------------------------------|----------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                                 |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater<br>(ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                       |
| hydrogen, $\text{H}_2$        | “pops” with a lighted splint                                                     |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                        |
| sulfur dioxide, $\text{SO}_2$ | turns acidified aqueous potassium dichromate(VI) (aq) from orange to green       |

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**CHEMISTRY**

Paper 32 Advanced Practical Skills

**9701/34**

**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 10 and 11.

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 **11** printed pages and **1** blank page.



# 1 Read through question 1 before starting any practical work.

For  
Examiner's  
Use

You are provided with the following reagents.

- weighing bottles/tubes labelled **FB 1**, **FB 2** and **FB 3**; each containing a different mass of sodium hydrogencarbonate,  $\text{NaHCO}_3$
- additional solid sodium hydrogencarbonate (approximately 10 g)
- FB 4**,  $3.0 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$

The reaction of sodium hydrogencarbonate with hydrochloric acid is endothermic.

By measuring the maximum temperature decrease when the different masses of sodium hydrogencarbonate react with hydrochloric acid you are to determine the enthalpy change of neutralisation for 1 mol of  $\text{NaHCO}_3$  with  $\text{HCl}$ .

## (a) Method

- Weigh the bottle/tube containing the sodium hydrogencarbonate labelled **FB 1**.
- Support the plastic cup in the  $250 \text{ cm}^3$  beaker.
- Use the measuring cylinder to transfer  $30 \text{ cm}^3$  of **FB 4** into the plastic cup.
- Place the thermometer in the acid in the plastic cup and record the steady temperature of the acid.
- Add the contents of the weighed tube, **FB 1**, to the acid in the plastic cup, a little at a time with constant stirring.
- You should add the solid as quickly as possible – taking care to minimise any acid spray from the plastic cup.  
*Avoid breathing any fumes from the experiment.*
- Record the minimum temperature obtained in the reaction.
- Reweigh the emptied tube, **FB 1**, containing any remaining solid that was not tipped from the tube.
- Empty and rinse the plastic cup. Rinse the thermometer. Shake dry the plastic cup.
- Repeat the experiment using tubes labelled **FB 2** and **FB 3**. In each experiment use  $30 \text{ cm}^3$  of **FB 4**.

Carry out **two further experiments**.

Using the empty weighing bottles/tubes, labelled **FB 5** and **FB 6**, weigh two further masses of sodium hydrogencarbonate. Choose masses to enable you to plot an appropriate graph of temperature change against mass of sodium hydrogencarbonate.

## Results

Record your results in an appropriate form showing, for each experiment, the measurements of mass and temperature and the calculated temperature fall.

|      |  |
|------|--|
| i    |  |
| ii   |  |
| iii  |  |
| iv   |  |
| v    |  |
| vi   |  |
| vii  |  |
| viii |  |
| ix   |  |

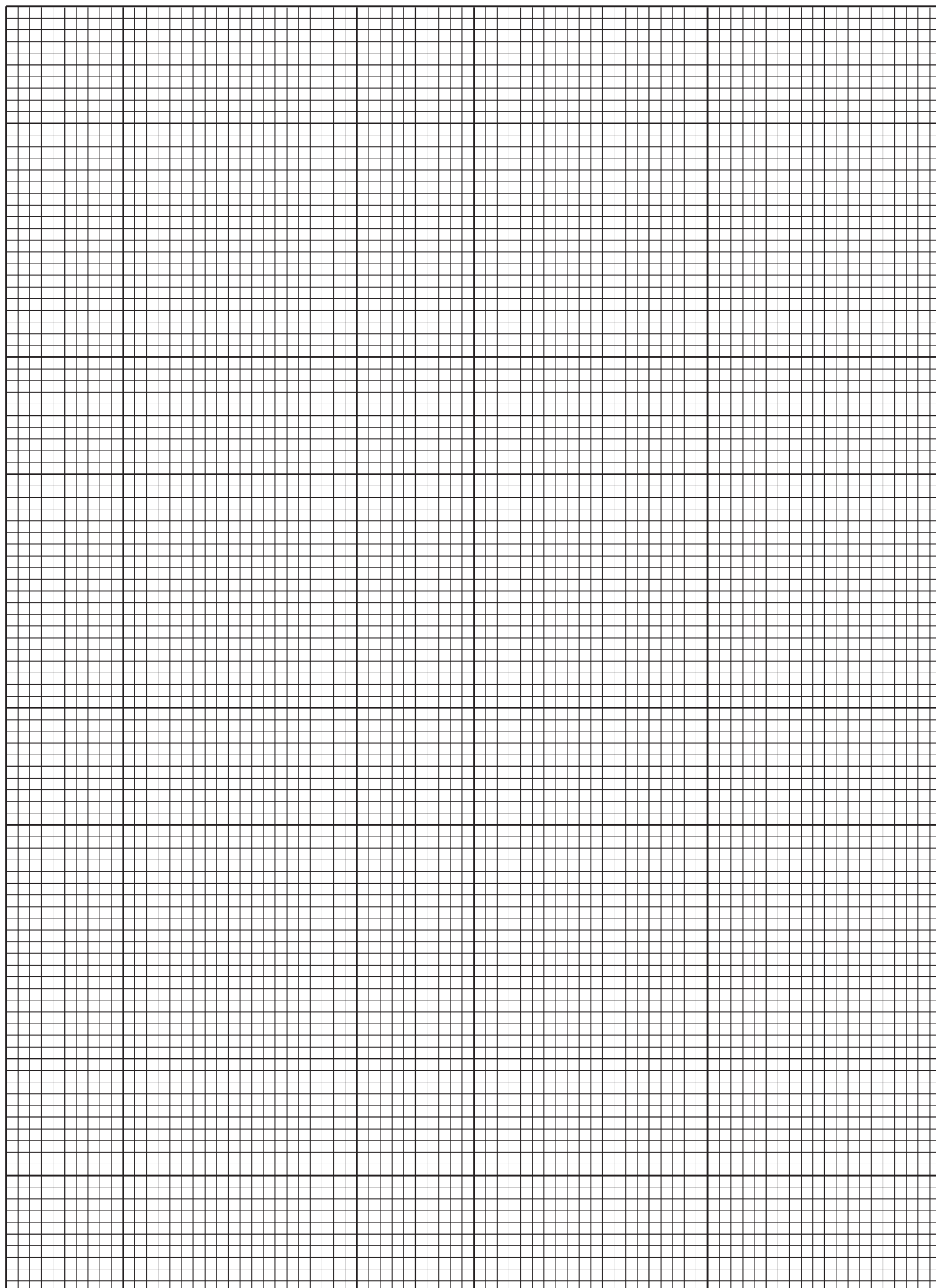
[9]

- (b) Use the grid below to plot a graph of decrease in temperature ( $y$ -axis) against the mass of sodium hydrogencarbonate added ( $x$ -axis).

Draw a line of best fit through the plotted points.

You should consider if the best-fit line passes through the origin (0,0) of the graph.

For  
Examiner's  
Use



|     |  |
|-----|--|
| i   |  |
| ii  |  |
| iii |  |
| iv  |  |

[4]

- (c) Explain why the mass of  $\text{NaHCO}_3$  is plotted on the *x-axis* rather than on the *y-axis*.

.....

..... [1]

- (d) Construct the balanced equation for the reaction of  $\text{NaHCO}_3$  with hydrochloric acid.

..... [1]

- (e) Calculate the gradient of your graph.

Show all of your working clearly, both construction lines on the graph and working in the calculation.

[3]

- (f) Although there is insufficient acid in  $30\text{ cm}^3$  of **FB 4** to neutralise 1 mol of  $\text{NaHCO}_3$  it is possible to calculate the theoretical fall in temperature for this reaction.

Use your answer from (e) to calculate this value.

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

The theoretical fall in temperature for 1 mol of  $\text{NaHCO}_3$  = .....  $^{\circ}\text{C}$  [1]

- (g) Calculate the theoretical enthalpy change for the neutralisation of 1 mol of  $\text{NaHCO}_3$  by hydrochloric acid. Give your answer in  $\text{kJ mol}^{-1}$  and include the correct sign for the reaction.

[4.3 J are absorbed or released when the temperature of  $1\text{ cm}^3$  of solution changes by  $1^{\circ}\text{C}$ .]

$\Delta H =$  .....  $\text{kJ mol}^{-1}$  [2]

- (h) Suggest **two** ways in which your apparatus could be modified to reduce transfer of heat from the surroundings to the solution in the apparatus.

modification 1 .....

.....

modification 2 .....

..... [1]

- (i) State and explain why the experiment would be more accurate if the volumes of **FB 4** had been measured using a burette instead of a measuring cylinder.

.....

..... [1]

- (j) The mass of  $\text{NaHCO}_3$  used in a further experiment and its associated temperature change are shown in the tables below.

- The mass was obtained on a balance reading to 1 decimal place.
- The thermometer used was graduated at 1 °C.

Complete the table to show the errors in these results.

|                                           |           |                                               |            |
|-------------------------------------------|-----------|-----------------------------------------------|------------|
| mass of $\text{NaHCO}_3$                  | 5.6 g     | temperature change                            | -12.0 °C   |
| maximum error in a single balance reading | ± ..... g | maximum error in a single thermometer reading | ± ..... °C |
| % error in measured mass                  | ..... %   | % error in temperature change                 | ..... %    |

[2]

- (k) Two students add 6.0 g of sodium carbonate to 50.00 cm<sup>3</sup> of 2.0 mol dm<sup>-3</sup> hydrochloric acid. Each student repeats the experiment a number of times. The thermometer readings and temperature changes obtained consistently by each student are shown below.

|           | initial temperature<br>/ °C | final temperature<br>/ °C | temperature rise<br>/ °C |
|-----------|-----------------------------|---------------------------|--------------------------|
| student 1 | 20.0                        | 28.0                      | 8.0                      |
| student 2 | 19.0                        | 27.0                      | 8.0                      |

Suggest the type of error shown by these results.

..... [1]

[Total: 26]

- 2 **FB 7** and **FB 8** are aqueous solutions of salts. One of these contains **two** cations and one anion.  
The other contains one cation and one anion.  
Both **FB 7** and **FB 8** have a common cation.

You will carry out tests to deduce the following.

- the cations present in each solution
- whether a sulfate ion is present in either solution

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate and the colour of the precipitate

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 directly with a Bunsen burner a boiling-tube MUST be used.**

Rinse and reuse test-tubes where possible.

- (a) Use information from the Qualitative Analysis Notes on page 11 to select a pair of reagents that, **used together**, determine whether a sulfate ion is present in either solution.

The reagents are .....

followed by ..... .

[1]

- (b) Use your chosen reagents to carry out tests on **FB 7** and **FB 8**.  
Record your results in an appropriate form in the space below.

[2]

- (c) From your observations in (b) show with a tick which of the following statements is true.

|                                           |  |
|-------------------------------------------|--|
| <b>FB 7</b> contains the sulfate ion      |  |
| <b>FB 8</b> contains the sulfate ion      |  |
| neither solution contains the sulfate ion |  |

Explain the evidence that supports your conclusion.

.....

..... [1]

- (d) Carry out the following tests on the solutions **FB 7** and **FB 8**.  
Record your observations below.

| <i>test</i>                                                                                      | <i>observations</i> |             |
|--------------------------------------------------------------------------------------------------|---------------------|-------------|
|                                                                                                  | <b>FB 7</b>         | <b>FB 8</b> |
| To 1 cm depth of solution in a boiling-tube, add 2 cm depth of aqueous sodium hydroxide;<br>then |                     |             |
| warm the solution gently.<br><br><b>Care is needed when heating aqueous sodium hydroxide.</b>    |                     |             |
| To 1 cm depth of solution in a test-tube, add 2 cm depth of aqueous ammonia.                     |                     |             |

[3]

- (e) To 1 cm depth of **FB 7** in a test-tube add 1 cm depth of sodium hydroxide.  
Leave to stand for a few minutes.

observation

.....

..... [1]

- (f) From your observations in (d) and (e) you should be able to identify the common cation in the solutions and the second cation in **one** of the solutions.

The common cation present in both solutions is .....

The second cation contained in one of the solutions is .....

Explain how your observations support your conclusions for

- (i) the common cation,

.....  
 .....

- (ii) the second cation.

.....  
 .....

[1]

**Read through the remainder of question 2 before starting further practical work.**

**Heat a half-full 250 cm<sup>3</sup> beaker of water for use as a hot water-bath.**

- (g) **FB 9, FB 10, FB 11** and **FB 12** are organic compounds. Each contains one of the following different functional groups.

- primary alcohol
- secondary alcohol
- aldehyde
- ketone

You are to react each of these compounds with some of the following reagents.

- acidified aqueous potassium dichromate(VI)
- 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent
- ammoniacal silver nitrate (Tollens' reagent)

You are provided with the first two reagents. You must prepare the last of these reagents, Tollens' reagent, immediately before use. Follow the instructions in the box below.

To 2 cm depth of aqueous silver nitrate in a boiling-tube add ½ cm depth of aqueous sodium hydroxide. This will produce a brown precipitate of silver(I) oxide. Add aqueous ammonia a little at a time, with continuous shaking, until the brown precipitate **just** dissolves. **Do not add an excess of aqueous ammonia.**

In each of the following tests add a few drops of the reagent to 1 cm depth of **FB 9**, **FB 10**, **FB 11** and **FB 12** in separate test-tubes.

In the tests using acidified potassium dichromate(VI) and Tollens' reagent, if no initial reaction is seen, warm that tube and its contents in your hot water-bath. There is no need to heat any tube to which you have added 2,4-DNPH reagent.

Do **not** heat any tube with a naked flame.

Record your results in the table below.

Do **not** carry out tests for the shaded boxes.

| reagent                            | observations |       |       |       |
|------------------------------------|--------------|-------|-------|-------|
|                                    | FB 9         | FB 10 | FB 11 | FB 12 |
| acidified potassium dichromate(VI) |              |       |       |       |
| 2,4-DNPH reagent                   |              |       |       |       |
| Tollens' reagent                   |              |       |       |       |

[3]

- (h) State which of the solutions contain alcohols. Explain the observations leading to your conclusion.

**FB** ..... and **FB** ..... contain alcohols.

explanation .....

.....

State which solution contains the ketone. Explain the observations leading to your conclusion.

**FB** ..... contains the ketone.

explanation .....

.....

[2]

[Total: 14]

Key: [ ppt. = precipitate. ]

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | —                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | no ppt. (if reagents are pure)                                                     | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt. soluble in excess<br>giving dark green solution                    | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | blue ppt. soluble in excess<br>giving dark blue solution                           |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| lead(II),<br>Pb <sup>2+</sup> (aq)             | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

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

## 2 Reactions of anions

| <i>ion</i>                                      | <i>reaction</i>                                                                                                                                                                                           |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$                | $\text{CO}_2$ liberated by dilute acids                                                                                                                                                                   |
| chromate(VI),<br>$\text{CrO}_4^{2-}(\text{aq})$ | yellow solution turns orange with $\text{H}^+(\text{aq})$ ;<br>gives yellow ppt. with $\text{Ba}^{2+}(\text{aq})$ ;<br>gives bright yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                          |
| chloride,<br>$\text{Cl}^-(\text{aq})$           | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                               |
| bromide,<br>$\text{Br}^-(\text{aq})$            | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                     |
| iodide,<br>$\text{I}^-(\text{aq})$              | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ );<br>gives yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                                                           |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil                                                                                                                     |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil;<br>$\text{NO}$ liberated by dilute acids<br>(colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ in air) |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$       | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ or with $\text{Pb}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids);                                                                          |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$       | $\text{SO}_2$ liberated with dilute acids;<br>gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids)                                                                   |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                      |
|-------------------------------|----------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                                 |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater<br>(ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                       |
| hydrogen, $\text{H}_2$        | “pops” with a lighted splint                                                     |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                        |
| sulfur dioxide, $\text{SO}_2$ | turns acidified aqueous potassium dichromate(VI) from orange to green            |

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**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 |  |
|            |  |

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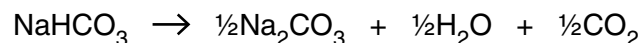
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- 1 You are required to find the molar enthalpy change for the decomposition of sodium hydrogencarbonate,  $\text{NaHCO}_3$ .

For  
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Use



**FA 1** is anhydrous sodium hydrogencarbonate.

**FA 2** is anhydrous sodium carbonate.

**FA 3** is  $4.0 \text{ mol dm}^{-3}$  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:**  $4.0 \text{ mol dm}^{-3}$  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.**

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

For  
Examiner's  
Use

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.

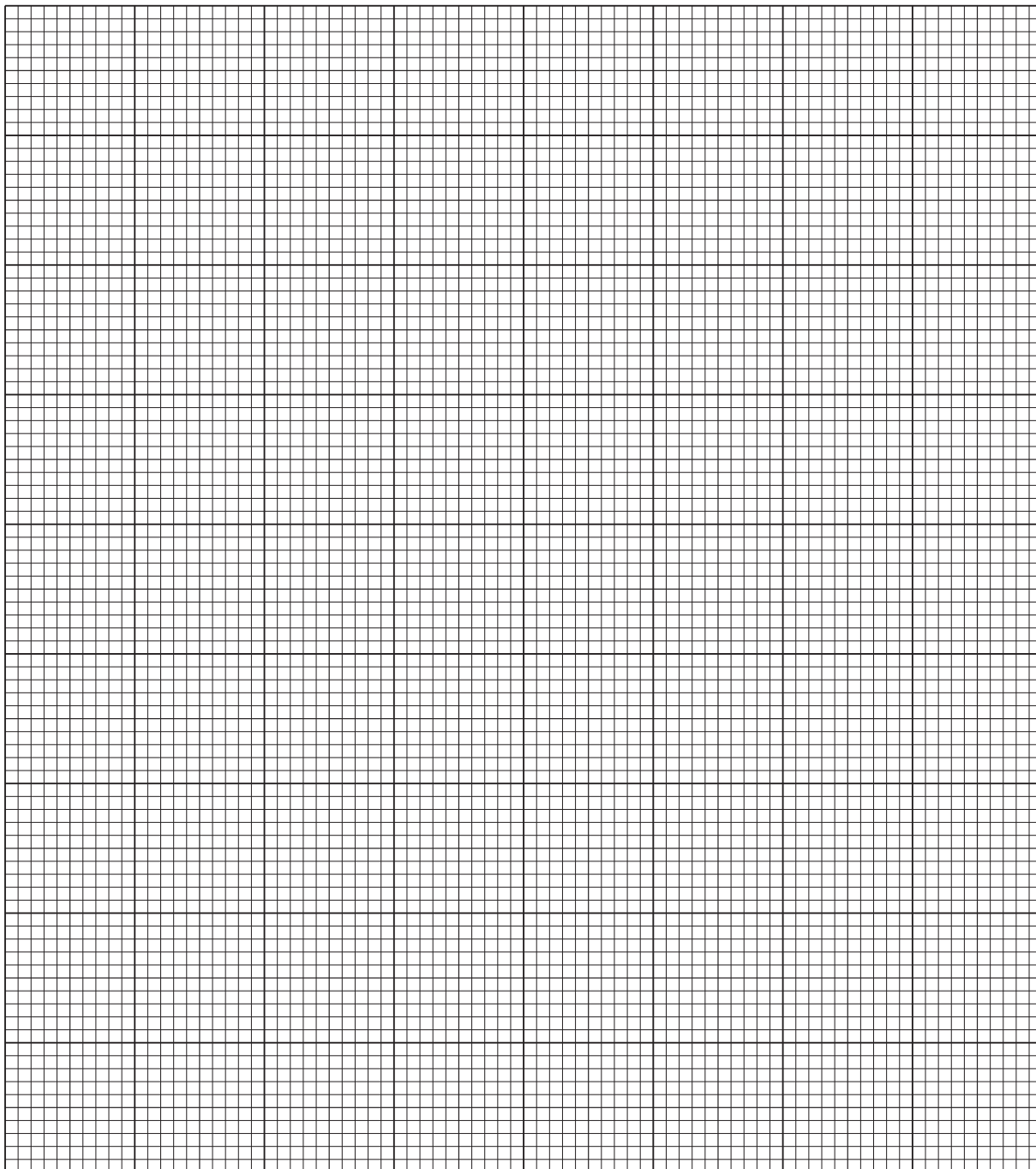
- Weigh the stoppered tube labelled **FA 1** containing sodium hydrogencarbonate.
- Use a 50 cm<sup>3</sup> measuring cylinder to transfer 50 cm<sup>3</sup> of **FA 3** into a 250 cm<sup>3</sup> beaker.
- Stir the acid in the beaker with the thermometer. Record the temperature of the acid; this is the 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]

**(b) Graph plotting**For  
Examiner's  
Use

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,  $\Delta T_1$ , 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,  $\Delta T_1$ , 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**,  $\text{NaHCO}_3$ , 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,  $\Delta H_{\text{neutralisation}}(\text{NaHCO}_3)$ .Make certain that your answer is given in  $\text{kJ mol}^{-1}$  and has the appropriate sign.

$$\Delta H_{\text{neutralisation}}(\text{NaHCO}_3) = \begin{array}{cc} \text{.....} & \text{.....} \\ \text{sign} & \text{calculated value} \end{array} \text{ kJ mol}^{-1}.$$

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

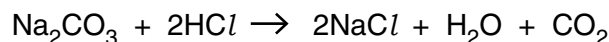
.....

.....

.....

[3]

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**(d) Determining the molar enthalpy change of neutralisation between FA 2 and FA 3**For  
Examiner's  
Use

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<sub>2</sub>CO<sub>3</sub>** 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<sub>2</sub>CO<sub>3</sub>**.
- Use a 50cm<sup>3</sup> measuring cylinder to transfer 50cm<sup>3</sup> of **FA 3** into the rinsed and dried 250cm<sup>3</sup> 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<sub>2</sub>CO<sub>3</sub> 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<sub>2</sub>CO<sub>3</sub>**, 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 7.0g and 7.5g 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 50cm<sup>3</sup> 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 / °C              |              |              |
| maximum temperature obtained / °C             |              |              |
| temperature rise, $\Delta T_2$ / °C           |              |              |

[6]

**(e) Calculations**For  
Examiner's  
Use

Working should be shown in all calculations.

- (i) Use the equation below and the temperature rise,  $\Delta T_2$ , 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,  $\Delta H_{\text{neutralisation}}(\text{Na}_2\text{CO}_3)$ .  
Make certain that your answer is given in  $\text{kJ mol}^{-1}$  and has the appropriate sign.

$$\Delta H_{\text{neutralisation}}(\text{Na}_2\text{CO}_3) = \text{.....} \quad \text{.....} \quad \text{kJ mol}^{-1}.$$

*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]

**(f) Calculating the enthalpy change of decomposition of FA 1,  $\Delta H_{\text{decomposition}}(\text{NaHCO}_3)$** 

Use your values for  $\Delta H_{\text{neutralisation}}(\text{NaHCO}_3)$  and  $\Delta H_{\text{neutralisation}}(\text{Na}_2\text{CO}_3)$  in the expression below to calculate a value for the molar enthalpy change of decomposition,  $\Delta H_{\text{decomposition}}(\text{NaHCO}_3)$ , for **FA 1**.

$$\Delta H_{\text{decomposition}}(\text{NaHCO}_3) = \Delta H_{\text{neutralisation}}(\text{NaHCO}_3) - \frac{1}{2}\Delta H_{\text{neutralisation}}(\text{Na}_2\text{CO}_3)$$

$$\Delta H_{\text{decomposition}}(\text{NaHCO}_3) = \text{.....} \text{ kJ mol}^{-1}.$$

*sign                      calculated value*

[1]

**(g) Evaluation**

An alternative method for the determination of  $\Delta H_{\text{decomposition}}(\text{NaHCO}_3)$  gave a value of +42.5 kJ mol<sup>-1</sup>.

The value you have obtained may be significantly different from this value.

Calculate the difference between your value of  $\Delta H_{\text{decomposition}}(\text{NaHCO}_3)$  and that obtained by the alternative method.

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

$$\text{difference} = \text{.....} \text{ kJ mol}^{-1}$$

$$\text{percentage difference} = \text{.....} \%$$

[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]

- 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.

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### 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 |             |             |
|---------|--------------|-------------|-------------|
|         | <b>FA 4</b>  | <b>FA 5</b> | <b>FA 6</b> |
|         |              |             |             |
|         |              |             |             |

[2]

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

| solution    | carbonate | chloride | evidence |
|-------------|-----------|----------|----------|
| <b>FA 4</b> |           |          |          |
| <b>FA 5</b> |           |          |          |
| <b>FA 6</b> |           |          |          |

[2]

**(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 |
| <b>(i)</b>   | 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.                                                                   |              |      |      |       |
| <b>(ii)</b>  | 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.                                                                                    |              |      |      |       |
| <b>(iii)</b> | 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. |              |      |      |       |
|              | <b>The reagent is</b>                                                                                                                                                                                                                    |              |      |      |       |

[7]

For  
Examiner's  
Use

|     |  |
|-----|--|
| i   |  |
| ii  |  |
| iii |  |
| iv  |  |
| v   |  |
| vi  |  |
| vii |  |

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

| solution | cation | evidence |
|----------|--------|----------|
| FA 7     |        |          |
| FA 9     |        |          |
| FA 10    |        |          |

For  
Examiner's  
Use

[2]

[Total: 15]

## Qualitative Analysis Notes

Key: [ ppt. = precipitate. ]

## 1 Reactions of aqueous cations

| ion                                            | reaction with                                                                      |                                                                                    |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|                                                | NaOH(aq)                                                                           | NH <sub>3</sub> (aq)                                                               |
| aluminium,<br>Al <sup>3+</sup> (aq)            | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| ammonium,<br>NH <sub>4</sub> <sup>+</sup> (aq) | no ppt.<br>ammonia produced on heating                                             | –                                                                                  |
| barium,<br>Ba <sup>2+</sup> (aq)               | no ppt. (if reagents are pure)                                                     | no ppt.                                                                            |
| calcium,<br>Ca <sup>2+</sup> (aq)              | white ppt. with high [Ca <sup>2+</sup> (aq)]                                       | no ppt.                                                                            |
| chromium(III),<br>Cr <sup>3+</sup> (aq)        | grey-green ppt. soluble in excess<br>giving dark green solution                    | grey-green ppt.<br>insoluble in excess                                             |
| copper(II),<br>Cu <sup>2+</sup> (aq)           | pale blue ppt.<br>insoluble in excess                                              | blue ppt. soluble in excess<br>giving dark blue solution                           |
| iron(II),<br>Fe <sup>2+</sup> (aq)             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             | green ppt. turning brown on contact<br>with air<br>insoluble in excess             |
| iron(III),<br>Fe <sup>3+</sup> (aq)            | red-brown ppt.<br>insoluble in excess                                              | red-brown ppt.<br>insoluble in excess                                              |
| lead(II),<br>Pb <sup>2+</sup> (aq)             | white ppt.<br>soluble in excess                                                    | white ppt.<br>insoluble in excess                                                  |
| magnesium,<br>Mg <sup>2+</sup> (aq)            | white ppt.<br>insoluble in excess                                                  | white ppt.<br>insoluble in excess                                                  |
| manganese(II),<br>Mn <sup>2+</sup> (aq)        | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess | off-white ppt. rapidly turning brown<br>on contact with air<br>insoluble in excess |
| zinc,<br>Zn <sup>2+</sup> (aq)                 | white ppt.<br>soluble in excess                                                    | white ppt.<br>soluble in excess                                                    |

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

## 2 Reactions of anions

| <i>ion</i>                                      | <i>reaction</i>                                                                                                                                                                                           |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$                | $\text{CO}_2$ liberated by dilute acids                                                                                                                                                                   |
| chromate(VI),<br>$\text{CrO}_4^{2-}(\text{aq})$ | yellow solution turns orange with $\text{H}^+(\text{aq})$ ;<br>gives yellow ppt. with $\text{Ba}^{2+}(\text{aq})$ ;<br>gives bright yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                          |
| chloride,<br>$\text{Cl}^-(\text{aq})$           | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                               |
| bromide,<br>$\text{Br}^-(\text{aq})$            | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ );<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                     |
| iodide,<br>$\text{I}^-(\text{aq})$              | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ );<br>gives yellow ppt. with $\text{Pb}^{2+}(\text{aq})$                                                           |
| nitrate,<br>$\text{NO}_3^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil                                                                                                                     |
| nitrite,<br>$\text{NO}_2^-(\text{aq})$          | $\text{NH}_3$ liberated on heating with $\text{OH}^-(\text{aq})$ and $\text{Al}$ foil;<br>$\text{NO}$ liberated by dilute acids<br>(colourless $\text{NO} \rightarrow$ (pale) brown $\text{NO}_2$ in air) |
| sulfate,<br>$\text{SO}_4^{2-}(\text{aq})$       | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acid) or<br>gives white ppt. with $\text{Pb}^{2+}(\text{aq})$                                                        |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$       | $\text{SO}_2$ liberated with dilute acids;<br>gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acid)                                                                    |

## 3 Tests for gases

| <i>gas</i>                    | <i>test and test result</i>                                                      |
|-------------------------------|----------------------------------------------------------------------------------|
| ammonia, $\text{NH}_3$        | turns damp red litmus paper blue                                                 |
| carbon dioxide, $\text{CO}_2$ | gives a white ppt. with limewater<br>(ppt. dissolves with excess $\text{CO}_2$ ) |
| chlorine, $\text{Cl}_2$       | bleaches damp litmus paper                                                       |
| hydrogen, $\text{H}_2$        | "pops" with a lighted splint                                                     |
| oxygen, $\text{O}_2$          | relights a glowing splint                                                        |
| sulfur dioxide, $\text{SO}_2$ | turns acidified aqueous potassium dichromate(VI) (aq) from orange to green       |

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