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## 9701/33

February/March 2016

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

## READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.  
Give details of the practical session and laboratory where appropriate, in the boxes provided.  
Write in dark blue or black pen.  
You may use an HB pencil for any diagrams or graphs.  
Do not use staples, paper clips, glue or correction fluid.  
**DO NOT WRITE IN ANY BARCODES.**

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

Qualitative Analysis Notes are printed on pages 10 and 11.  
A copy of the Periodic Table is printed on page 12.

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> |
|                   |

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

This document consists of **12** printed pages.

- 1 You will determine the enthalpy change,  $\Delta H$ , of the reaction between magnesium and hydrochloric acid. To do this you will measure the change in temperature when a piece of magnesium ribbon reacts with an excess of hydrochloric acid.



**FA 1** is hydrochloric acid,  $\text{HCl}$ .

**FA 2** is magnesium ribbon,  $\text{Mg}$ .

**(a) Method**

- Weigh the **FA 2** and record the mass in the space below.
- Support the plastic cup in the  $250\text{ cm}^3$  beaker.
- Coil the **FA 2** so that it will fit into the bottom of the plastic cup then remove it.
- Use the measuring cylinder to transfer  $25\text{ cm}^3$  of **FA 1** into the plastic cup.
- Place the thermometer in the acid and tilt the cup if necessary so that the bulb of the thermometer is fully covered. Record the temperature at time = 0 in the table of results.
- Start timing and do not stop the clock until the whole experiment has been completed at time = 8 minutes.
- Record the temperature of the acid every half minute for 2 minutes.
- At time =  $2\frac{1}{2}$  minutes carefully drop the coil of **FA 2** into the acid and stir the mixture.
- Record the temperature of the mixture at time = 3 minutes and complete the table by recording the temperature every half minute. Stir the mixture between thermometer readings.

**Results**

mass of **FA 2** = ..... g

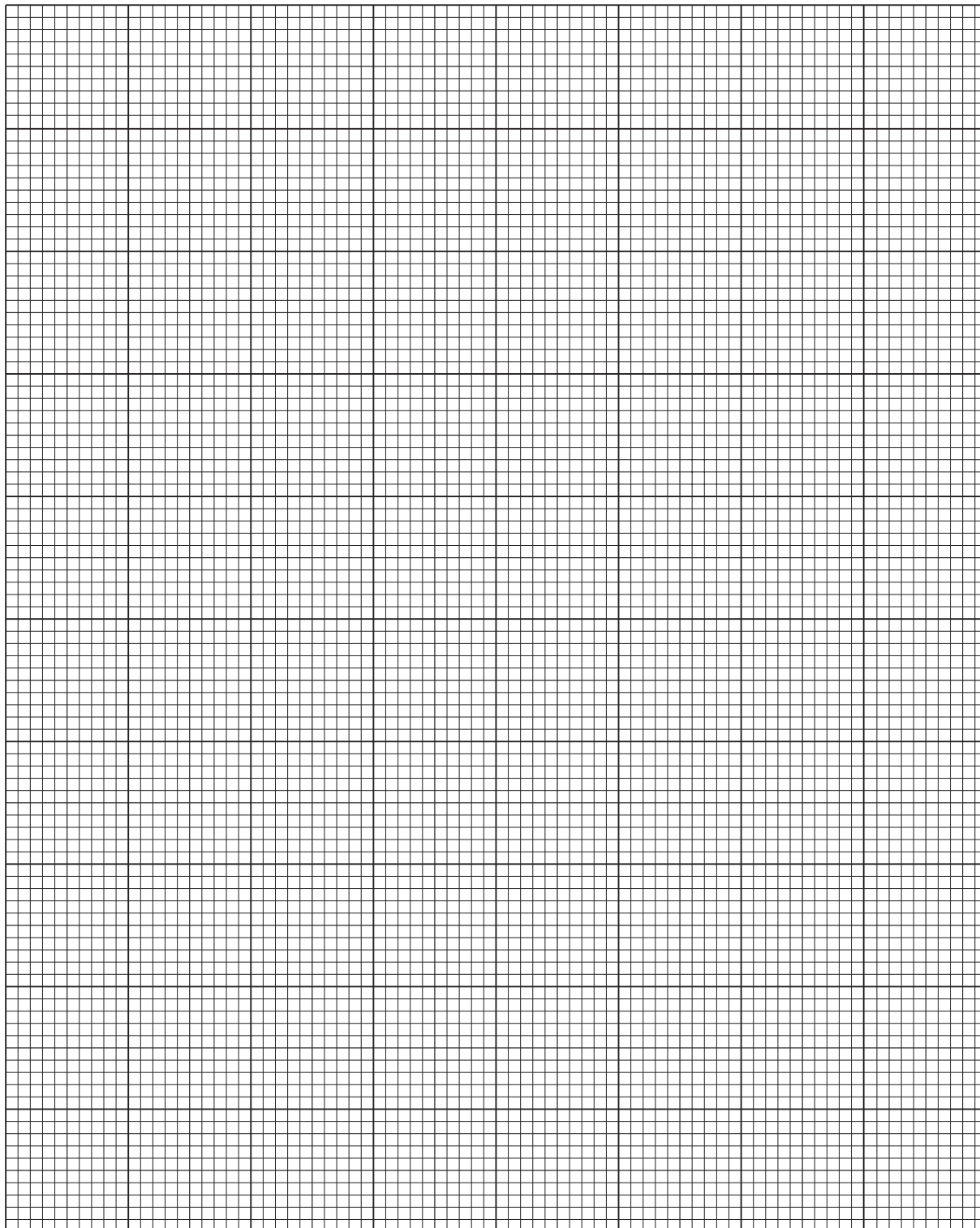
|                                  |   |               |   |                |   |                |   |                |   |
|----------------------------------|---|---------------|---|----------------|---|----------------|---|----------------|---|
| time / minutes                   | 0 | $\frac{1}{2}$ | 1 | $1\frac{1}{2}$ | 2 | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | 4 |
| temperature / $^{\circ}\text{C}$ |   |               |   |                |   |                |   |                |   |

|                                  |                |   |                |   |                |   |                |   |
|----------------------------------|----------------|---|----------------|---|----------------|---|----------------|---|
| time / minutes                   | $4\frac{1}{2}$ | 5 | $5\frac{1}{2}$ | 6 | $6\frac{1}{2}$ | 7 | $7\frac{1}{2}$ | 8 |
| temperature / $^{\circ}\text{C}$ |                |   |                |   |                |   |                |   |

|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |

[4]

- (b) Plot a graph of temperature on the y-axis against time on the x-axis on the grid below. The scale for the temperature axis should extend  $10^{\circ}\text{C}$  greater than the maximum temperature you recorded. You will use the graph to determine the theoretical maximum temperature rise at  $2\frac{1}{2}$  minutes.



|     |  |
|-----|--|
| I   |  |
| II  |  |
| III |  |
| IV  |  |

Draw two lines of best fit through the points on your graph, the first for the temperature before adding **FA 2** and the second for the cooling of the mixture once the reaction is complete. Extrapolate the two lines to  $2\frac{1}{2}$  minutes, draw a vertical line between the two and determine the theoretical rise in temperature at this time.

theoretical rise in temperature at  $2\frac{1}{2}$  minutes = .....  $^{\circ}\text{C}$  [4]

**(c) Calculations**

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

- (i) Use your answer to (b) to calculate the heat energy, in joules, given out when **FA 2** is added to **FA 1**.  
(Assume 4.2 J of heat energy raises the temperature of 1.0 cm<sup>3</sup> of the mixture by 1.0 °C.)

heat energy evolved = ..... J

- (ii) Use the Periodic Table on page 12 and your answer to (i) to calculate the enthalpy change, in kJ mol<sup>-1</sup>, when 1 mole of magnesium, **FA 2**, reacts with hydrochloric acid, **FA 1**.

enthalpy change = ..... kJ mol<sup>-1</sup>  
(sign) (value) [3]

- (d) A student carried out the same procedure using the same concentration of sulfuric acid, H<sub>2</sub>SO<sub>4</sub>, instead of hydrochloric acid. Before starting the experiment the student predicted that the enthalpy change would be twice that with hydrochloric acid.  
Was the student correct? Explain your answer.

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

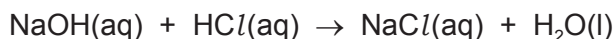
- (e) The enthalpy change determined in (c)(ii) is only an approximation of the actual value.

Suggest and explain one improvement you would make to the method in (a) to increase the accuracy of the experiment.

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

[Total: 13]

- 2 You will determine the concentration of the hydrochloric acid used in **Question 1** by titration of a diluted solution of **FA 1** with aqueous sodium hydroxide of known concentration.



**FA 3** is a diluted solution of **FA 1**, hydrochloric acid,  $\text{HCl}$ . **FA 3** was prepared by running  $25.00 \text{ cm}^3$  of **FA 1** into a volumetric flask and adding distilled water until the total volume was  $250.0 \text{ cm}^3$ .

**FA 4** is  $0.100 \text{ mol dm}^{-3}$  sodium hydroxide,  $\text{NaOH}$ .

bromophenol blue indicator

**(a) Method**

- Fill the burette with **FA 4**.
- Pipette  $25.0 \text{ cm}^3$  of **FA 3** into a conical flask.
- Add about 10 drops of bromophenol blue.
- Perform a rough titration and record your burette readings in the space below. The end point is reached when the solution becomes a permanent blue-violet colour.

The rough titre is .....  $\text{cm}^3$ .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make certain any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 4** added in each accurate titration.

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

[7]

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

$25.0 \text{ cm}^3$  of **FA 3** required .....  $\text{cm}^3$  of **FA 4**.  
[1]

**(c) Calculations**

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

- (i) Calculate the number of moles of sodium hydroxide present in the volume of **FA 4** recorded in **(b)**.

moles of NaOH = ..... mol

- (ii) Use your answer to **(i)** and the equation on page 5 to determine the number of moles of hydrochloric acid present in 25.0 cm<sup>3</sup> of **FA 3**.

moles of HCl = ..... mol

- (iii) Use your answer to **(ii)**, and any relevant information given on page 5, to calculate the concentration, in mol dm<sup>-3</sup>, of hydrochloric acid in **FA 1**.

concentration of HCl in **FA 1** = ..... mol dm<sup>-3</sup>

- (iv) Show, by calculation, that the hydrochloric acid in **Question 1** was in excess.

[5]

- (d) The error in the volume reading of a pipette is  $\pm 0.06 \text{ cm}^3$  which gives a maximum percentage error of 0.24% for 25.0 cm<sup>3</sup> of **FA 3**.  
The error in a single burette reading is  $\pm 0.05 \text{ cm}^3$ .

Calculate the maximum percentage error in the volume of **FA 4** used in **(b)** and deduce which solution, **FA 3** or **FA 4**, was measured more accurately.

maximum percentage error for volume of **FA 4** in **(b)** = ..... %

..... was measured more accurately.

[1]

[Total: 14]

### 3 Qualitative Analysis

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

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

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

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

Marks are **not** given for chemical equations.

**No additional tests for ions present should be attempted.**

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

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

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

(a) **FA 5** and **FA 6** are solutions each containing one cation and one anion.

Use a 1 cm depth of **FA 5** or **FA 6** in a test-tube to carry out the following tests on the two solutions and record your observations.

| <i>test</i>                                                           | <i>observations</i> |             |
|-----------------------------------------------------------------------|---------------------|-------------|
|                                                                       | <b>FA 5</b>         | <b>FA 6</b> |
| Add aqueous sodium hydroxide.                                         |                     |             |
| Add aqueous ammonia.                                                  |                     |             |
| Add a 1 cm depth of dilute hydrochloric acid, then                    |                     |             |
| transfer the mixture into a boiling tube and warm gently.             |                     |             |
| Add two or three drops of acidified aqueous potassium manganate(VII). |                     |             |
| Add a 1 cm depth of aqueous barium chloride or barium nitrate, then   |                     |             |
| add dilute hydrochloric acid.                                         |                     |             |

Identify as many of the ions present in **FA 5** and **FA 6** as possible from your observations. If you are unable to identify any of the ions from your observations, write 'unknown' in the space.

|        | <b>FA 5</b> | <b>FA 6</b> |
|--------|-------------|-------------|
| cation |             |             |
| anion  |             |             |

[8]

- (b) **FA 7** is a solid with an anion containing the same element as one of the anions in either **FA 5** or **FA 6** but in a different oxidation state. Relevant anions are listed in the Qualitative Analysis Notes on page 11.

Place a spatula measure of **FA 7** in a boiling tube and add a 2 cm depth of distilled water. Shake the boiling tube to dissolve the solid and make a solution of **FA 7**.

- (i) Select reagents to test whether the anion in **FA 7** contains the same element as the anion in **FA 5**.

Carry out your test(s) on the solution of **FA 7** and record your observations **and conclusions** in a suitable form in the space below.

reagents for testing **FA 7**

.....

observations and conclusions

- (ii) Select reagents to test whether the anion in **FA 7** contains the same element as the anion in **FA 6**.

Carry out your test(s) on the solution of **FA 7** and record your observations **and conclusions** in a suitable form in the space below.

reagents for testing **FA 7**

.....

observations and conclusions

[5]

[Total: 13]

## 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)               | faint white ppt. is nearly always<br>observed unless 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.<br>soluble in excess                                               | 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                                              |
| 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                                                    |

## 2 Reactions of anions

| <i>ion</i>                                | <i>reaction</i>                                                                                                                                                                                           |
|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| carbonate,<br>$\text{CO}_3^{2-}$          | $\text{CO}_2$ liberated by dilute acids                                                                                                                                                                   |
| chloride,<br>$\text{Cl}^-(\text{aq})$     | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$ )                                                                                                                     |
| bromide,<br>$\text{Br}^-(\text{aq})$      | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$ )                                                                                                           |
| iodide,<br>$\text{I}^-(\text{aq})$        | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$ )                                                                                                                  |
| 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 acids)                                                                                                               |
| sulfite,<br>$\text{SO}_3^{2-}(\text{aq})$ | 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 (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                                                     |

The Periodic Table of Elements

| Group |   |  |  |  |  |  |  |  |  |  |  |  |  |    |    |    |    |    |    |
|-------|---|--|--|--|--|--|--|--|--|--|--|--|--|----|----|----|----|----|----|
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lanthanoids

actinoids

|           |         |              |           |            |           |           |            |           |             |             |         |              |           |            |
|-----------|---------|--------------|-----------|------------|-----------|-----------|------------|-----------|-------------|-------------|---------|--------------|-----------|------------|
| 57        | 58      | 59           | 60        | 61         | 62        | 63        | 64         | 65        | 66          | 67          | 68      | 69           | 70        | 71         |
| La        | Ce      | Pr           | Nd        | Pm         | Sm        | Eu        | Gd         | Tb        | Dy          | Ho          | Er      | Tm           | Yb        | Lu         |
| lanthanum | cerium  | praseodymium | neodymium | promethium | samarium  | europtium | gadolinium | terbium   | dysprosium  | holmium     | erbium  | thulium      | ytterbium | lutetium   |
| 138.9     | 140.1   | 140.9        | 144.4     | —          | 150.4     | 152.0     | 157.3      | 158.9     | 162.5       | 164.9       | 167.3   | 168.9        | 173.1     | 175.0      |
| 89        | 90      | 91           | 92        | 93         | 94        | 95        | 96         | 97        | 98          | 99          | 100     | 101          | 102       | 103        |
| Ac        | Th      | Pa           | U         | Np         | Pu        | Am        | Cm         | Bk        | Cf          | Es          | Fm      | Md           | No        | Lr         |
| actinium  | thorium | protactinium | uranium   | neptunium  | plutonium | americium | curium     | berkelium | californium | einsteinium | fermium | mendeleevium | nobelium  | lawrencium |
| —         | 232.0   | 231.0        | 238.0     | —          | —         | —         | —          | —         | —           | —           | —       | —            | —         | —          |