

CANDIDATE
NAME

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CENTRE
NUMBER

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NUMBER

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CHEMISTRY

9701/31

Paper 3 Advanced Practical Skills 1

October/November 2019

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 14 and 15.
A copy of the Periodic Table is printed on page 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
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

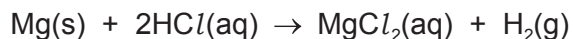


Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

- 1 In this experiment you will determine the concentration of a sample of hydrochloric acid. You will do this by measuring the volume of hydrogen produced when an excess of magnesium reacts with the acid.



FA 1 is magnesium powder, Mg.

FA 2 is hydrochloric acid, HCl.

(a) Method

- Weigh the container with **FA 1**. Record the mass.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm³ measuring cylinder completely with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so that the open end is just above the base of the tub.
- Use the 25 cm³ measuring cylinder to place 25.0 cm³ of **FA 2** into the reaction flask, labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X**, and place the end of the delivery tube into the inverted 250 cm³ measuring cylinder.
- Remove the bung from the neck of flask **X**. Tip all of **FA 1** into flask **X** and replace the bung **immediately**. Remove the flask from the clamp and swirl to mix the contents.
- Swirl the flask occasionally until no more gas is evolved. Replace the flask in the clamp.
- Measure and record the final volume of gas in the measuring cylinder.
- Weigh and record the mass of the container with any residual solid.
- Calculate and record the mass of **FA 1** used.

Keep FA 2 for use in Question 2.

[2]

(b) Calculations

- (i) Calculate the number of moles of hydrogen gas produced.
(Assume 1 mol of gas occupies 24.0 dm^3 at this temperature.)

moles of $\text{H}_2(\text{g}) = \dots\dots\dots \text{ mol}$
[1]

- (ii) Calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = $\dots\dots\dots \text{ mol dm}^{-3}$
[1]

- (iii) In this experiment the magnesium powder was in excess.

Calculate the mass of magnesium powder needed for complete reaction with all the hydrochloric acid in 25.0 cm^3 of **FA 2**.

mass of $\text{Mg} = \dots\dots\dots \text{ g}$
[1]

- (c) A student suggested two modifications to the method in (a) to give a more accurate value for the concentration.

For each suggestion, state whether you agree with the student and explain your answer.

Suggestion 1: Use magnesium ribbon rather than powdered magnesium; keep the rest of the experiment the same.

.....
.....

Suggestion 2: Use twice the mass of magnesium powder; keep the rest of the experiment the same.

.....
.....

[2]

- (d) Another student carried out the experiment in (a) but used less magnesium than that calculated in (b)(iii).

State and explain the effect this would have on the calculated concentration of hydrochloric acid in **FA 2**.

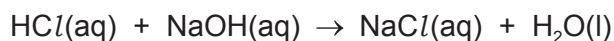
.....

.....

..... [1]

[Total: 8]

- 2 In this experiment you will determine the concentration of **FA 2** by titration using aqueous sodium hydroxide.



FA 2 is hydrochloric acid, HCl .

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

methyl orange indicator

(a) Method

Dilution of FA 2

- Fill the burette with **FA 2**.
- Run between 40.00 and 45.00 cm^3 from the burette into the 250 cm^3 volumetric flask.
- Record the volume used.
- Make the solution up to the 250 cm^3 mark by adding distilled water.
- Shake the flask thoroughly to ensure mixing.
- Label this solution of hydrochloric acid **FA 4**.

volume of **FA 2** used = ... cm^3

Titration

- Rinse the burette with distilled water and then with a little **FA 4**.
- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add several drops of methyl orange indicator.
- Perform a rough titration and record your burette readings.

The rough titre is cm^3 .

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

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

- (b) From your accurate titration results, obtain a value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **FA 3** required cm³ of **FA 4**.
[1]

(c) Calculations

- (i) Give your answers to (ii), (iii) and (iv) to the appropriate number of significant figures. [1]
(ii) Calculate the number of moles of hydrochloric acid that reacted with 25.0 cm³ of **FA 3**.

moles of HCl = ... mol
[1]

- (iii) Calculate the concentration of hydrochloric acid in **FA 4**.

concentration of HCl in **FA 4** = ... mol dm⁻³
[1]

- (iv) Calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... mol dm⁻³
[1]

- (d) Calculate the maximum percentage error in the volume of **FA 2** you added to the volumetric flask.

maximum percentage error = ... %
[1]

- (e) In **Question 1** and **Question 2** you have determined the concentration of **FA 2** by two different methods. Each method used has possible sources of error, for example in **Question 1** the largest source of error is escape of gas.

Apart from this error, state and explain a source of error for each method.

Question 1

.....

Question 2

.....

[2]

[Total: 16]

Qualitative Analysis

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

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

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

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

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

No additional tests for ions present should be attempted.

3 (a) FA 5 is a salt that contains two different cations and a single anion from those listed in the Qualitative Analysis Notes.

- (i) Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat **gently**.
Do not inhale the fumes.
 Record **all** your observations.

.....

.....

.....

..... [2]

- (ii) Pour a 4 cm depth of distilled water into a boiling tube. Add the remaining **FA 5** and stir carefully until the solid has dissolved. This solution is **FA 6**.
 Carry out the following tests on **FA 6** and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth in a test-tube, add aqueous ammonia.	
To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then	
warm the mixture.	

<i>test</i>	<i>observations</i>
To a 1 cm depth in a test-tube, add aqueous barium nitrate or aqueous barium chloride, then	
add dilute hydrochloric acid or dilute nitric acid.	

[4]

(iii) Identify the three ions in **FA 5**.

FA 5 contains , ... and

[2]

- (b) A student carried out Qualitative Analysis tests on a hydrated salt, **FA 7**, and concluded that it contained the ions K^+ , Cr^{3+} and SO_4^{2-} .
The relative formula mass of **FA 7** is 499.3.

Determine the formula of **FA 7**.

The formula of **FA 7** is

[2]

Question 3 continues on page 10.

(c) **FA 8** is a solution containing a single cation and a single anion, both of which are listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth in a test-tube, add a few drops of aqueous acidified potassium manganate(VII), then	
add starch indicator.	
To a 1 cm depth in a test-tube, add aqueous sodium hydroxide.	

[2]

(ii) Identify the two ions in **FA 8**.

FA 8 contains and [1]

(iii) Suggest an additional test you could carry out to confirm the presence of the anion in **FA 8**.

Carry out this test and record your result.

[2]

(iv) Give the ionic equation for the reaction you carried out using **FA 8** and sodium hydroxide. Include state symbols.

..... [1]

[Total: 16]

Qualitative Analysis Notes

1 Reactions of aqueous cations

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

2 Reactions of anions

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	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, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

The Periodic Table of Elements

Group																							
1	2													1		13		14	15	16	17	18	
														1 H hydrogen 1.0									

lanthanoids

actinoids

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

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Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

- 1 In this experiment you will determine the concentration of a solution of hydrochloric acid by titration with an alkali.

FA 1 is a solution containing 6.00 g dm^{-3} of sodium hydroxide, NaOH.

FA 2 is hydrochloric acid, HCl. (This solution is also used in **Questions 2** and **3**.)
methyl orange indicator

(a) Method

Dilution of FA 2

- Pipette **10.0 cm^3** of **FA 2** into the 250 cm^3 volumetric flask.
- Make the solution up to the mark using distilled water.
- Shake the solution in the volumetric flask thoroughly.
- This solution of hydrochloric acid is **FA 3**. Label the volumetric flask **FA 3**.

Titration

- Fill the burette with **FA 1**.
- Pipette **25.0 cm^3** of **FA 3** into a conical flask.
- Add several drops of methyl orange indicator.
- Perform a **rough** titration and record your burette readings in the space below.

The rough titre is cm^3 .

I	
II	
III	
IV	
V	
VI	
VII	

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FA 1** added in each accurate titration.

[7]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm³ of **FA 3** required cm³ of **FA 1**. [1]

(c) Calculations

- (i) Give your answers to (ii), (iii) and (iv) to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of sodium hydroxide, NaOH, in the volume of **FA 1** calculated in (b).

moles of NaOH = ... mol [1]

- (iii) Write the equation for the neutralisation of hydrochloric acid with sodium hydroxide. Include state symbols.

.....

Deduce the number of moles of hydrochloric acid that reacted with the sodium hydroxide in (ii).

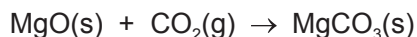
moles of hydrochloric acid = ... mol [1]

- (iv) Calculate the concentration, in mol dm⁻³, of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... mol dm⁻³ [2]

[Total: 13]

- 2 In this experiment you will determine the enthalpy change, ΔH , for the reaction shown.



To do this, you will determine the enthalpy changes for the reactions of magnesium oxide and magnesium carbonate with hydrochloric acid. Excess hydrochloric acid will be used in each reaction.

You will then use Hess' Law to calculate the enthalpy change for the reaction.

FA 2 is hydrochloric acid, HCl.

FA 4 is magnesium oxide, MgO.

FA 5 is magnesium carbonate, MgCO_3 .

- (a) Determination of the enthalpy change for the reaction of magnesium oxide, **FA 4**, with hydrochloric acid, **FA 2**

Method

- Support a plastic cup in the 250 cm³ beaker.
- Use the measuring cylinder to transfer 40 cm³ of **FA 2** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Weigh the container with **FA 4**. Record the mass.
- Add all the **FA 4** from the container to the **FA 2** in the plastic cup.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Weigh the container with any **FA 4** remaining. Record the mass.
- Calculate and record the mass of **FA 4** used.
- Calculate and record the temperature rise.

I	
II	
III	
IV	

[4]

(b) Calculations

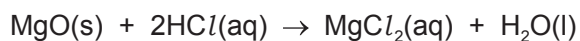
- (i) Calculate the energy produced during this reaction.
(Assume that 4.2 J are needed to raise the temperature of 1.0 cm³ of solution by 1.0 °C.)

energy produced = ... J [1]

- (ii) Calculate the number of moles of MgO used.

moles of MgO = ... mol [1]

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



enthalpy change = ... kJ mol⁻¹ [1]

sign *value*

- (c)** By means of a calculation, use your answer to **1(c)(iv)** to show that the hydrochloric acid, **FA 2**, was in excess for the reaction in **2(a)**.

(If you were unable to carry out the calculation in **1(c)(iv)**, you should assume that the concentration of HCl in **FA 2** is 3.75 mol dm^{-3} . This may not be the correct value.)

[1]

- Support the second plastic cup in the 250 cm³ beaker.
- Use the measuring cylinder to transfer 40 cm³ of **FA 2** into the plastic cup.
- Measure and record the initial temperature of the solution.
- Weigh the container with **FA 5**. Record the mass.
- Add approximately **half** of the **FA 5** from the container to the **FA 2** in the plastic cup.
- Stir constantly for approximately 30 seconds.
- Then add the remainder of the **FA 5**.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Weigh the container with any **FA 5** remaining. Record the mass.
- Calculate and record the mass of **FA 5** used.
- Calculate and record the temperature rise.

(ii) Apart from the change in temperature, what observations did you make during the reaction?

..... [1]

Calculate the enthalpy change for this reaction.



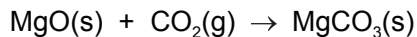
enthalpy change = ... kJ mol⁻¹ [1]

sign *value*

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

(If you were unable to calculate the enthalpy changes, assume that the magnitude of the enthalpy change in **(b)(iii)** is $110.3 \text{ kJ mol}^{-1}$ and the magnitude of the enthalpy change in **(d)(iii)** is 65.9 kJ mol^{-1} .)

Note: these may not be the correct magnitudes and the signs have been deliberately omitted.)



enthalpy change = ... kJ mol⁻¹ [1]
 sign *value*

- (f) Outline one improvement to the **method** that would lead to more accurate values for the enthalpy changes. Do **not** include a change to the apparatus used, such as the use of a lid.

..... [1]

- (g) Give the error in a single balance reading.

error = $\pm$ g

Which is greater, the percentage error in the mass of magnesium oxide used or the percentage error in the mass of magnesium carbonate used?

Percentage error is greater in

Calculate the **greater** percentage error.

greater % error = ... %
[2]

[Total: 16]

Qualitative Analysis

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

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

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

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

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

No additional tests for ions present should be attempted.

3 (a) You will investigate **FA 6**.

Pour a 1 cm depth of hydrochloric acid, **FA 2**, into a test-tube.
Add a small spatula measure of **FA 6** to the acid.
Record your observations.

.....

.....

.....

.....

What can you deduce from your observations? Explain your answer.

.....

.....

[3]

(b) (i) **FA 7** is a sodium compound containing an anion listed in the Qualitative Analysis Notes.

Heat a **small** spatula measure of **FA 7** in a hard-glass test-tube.
Heat strongly until no further change occurs, then leave the test-tube and contents to cool.

Record **all** your observations below.

.....

.....

.....

.....

[2]

- (ii) Dissolve the remaining **FA 7** in a 5 cm depth of distilled water in a boiling tube. Label this solution **FA 8**.

FA 9 is a solution of a different sodium compound. The anion is listed in the Qualitative Analysis Notes.

Carry out the following tests on **FA 8** and **FA 9** and record your observations in the table.

<i>test</i>	<i>observations with FA 8</i>	<i>observations with FA 9</i>
To a 1 cm depth in a test-tube, add a few drops of aqueous acidified potassium manganate(VII).		
To a 1 cm depth in a test-tube, add a few drops of aqueous barium chloride or aqueous barium nitrate.		
To a 1 cm depth in a boiling tube, add an equal volume of aqueous sodium hydroxide. Warm carefully , then		
add aluminium foil.		

[4]

- (iii) From your observations, suggest the anions present in **FA 8** and **FA 9**.

anion in **FA 8**

anion in **FA 9**

[1]

- (iv) Give the ionic equation for any reaction observed in (b)(ii). Include state symbols.

..... [1]

[Total: 11]

Qualitative Analysis Notes

1 Reactions of aqueous cations

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

2 Reactions of anions

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	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, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

The Periodic Table of Elements

Group																			
1	2													13	14	15	16	17	18
		1 H hydrogen 1.0																	
		Key atomic number atomic symbol name relative atomic mass																	
3 Li lithium 6.9	4 Be beryllium 9.0													5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3													13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8		
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3		
55 Cs caesium 132.9	56 Ba barium 137.3	lanthanoids		72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —	
87 Fr francium —	88 Ra radium —	actinoids		104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	114 Fl flerovium —	116 Lv livermorium —	118 Og oganeson —	119 Ts tennessine —	120 Lr lawrencium —		

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

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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

October/November 2019

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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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



Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

- 1 Hydrogen peroxide decomposes in a reaction catalysed by manganese(IV) oxide.



You will investigate this decomposition by measuring the volume of oxygen collected over a period of time. You will also use the volume of oxygen collected to calculate the concentration of the aqueous hydrogen peroxide.

FB 1 is aqueous hydrogen peroxide, H_2O_2 .

FB 2 is manganese(IV) oxide, MnO_2 .

(a) Method

- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder **completely** with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so that the open end is in the water just above the base of the tub.
- Use the 50 cm^3 measuring cylinder to place 30 cm^3 of **FB 1** and 20 cm^3 of distilled water into the reaction flask labelled **X**.
- Check that the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the end of the delivery tube into the 250 cm^3 measuring cylinder.
- Remove the bung from the neck of flask **X**. Add all of the **FB 2** into the hydrogen peroxide in the flask and replace the bung **immediately**. Start the stop-clock and leave it running until the end of the experiment.
- Remove the flask from the clamp and swirl to mix the contents, then replace the flask in the clamp.
- After 1 minute measure the volume of gas collected.
- After 4 minutes from the start of the experiment measure the volume of gas collected.

Keep FB 1 for use in Question 3.

Results

[3]

(b) Calculation

- (i) Use the volume of gas that you collected at 4 minutes to calculate the number of moles of hydrogen peroxide which had decomposed at this time.
(Assume 1 mol of gas occupies 24.0 dm³ at this temperature.)

moles of H₂O₂ = ... mol [1]

- (ii) Assume all the H₂O₂ had decomposed in 4 minutes.

Calculate the initial concentration of H₂O₂, in mol dm³, in **FB 1**.

initial concentration of H₂O₂ = ... mol dm⁻³ [2]

- (c) A student missed taking a reading at 1 minute so took a reading at 2 minutes instead. This student stated that after 2 minutes:

$$\text{rate of reaction} = \left(\frac{\text{volume of gas collected}}{2} \right) \text{ cm}^3 \text{ minute}^{-1}$$

Is the student correct? Explain your answer.

.....

 [2]

- (d) Another student carried out the experiment in (a) but used twice the mass of manganese(IV) oxide.

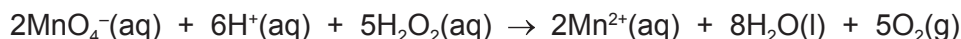
State and explain what effect this would have on the results obtained.

.....
 [1]

[Total: 9]

- 2 In **Question 1** you determined the concentration of a sample of aqueous hydrogen peroxide, **FB 1**, by measuring the volume of oxygen produced when it decomposed.

In **Question 2** you will determine the concentration of a different sample of aqueous hydrogen peroxide by titration with acidified manganate(VII) ions. The equation for the reaction is shown.



FB 3 is aqueous hydrogen peroxide, H_2O_2 .

FB 4 is $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII), KMnO_4 .

FB 5 is 1 mol dm^{-3} sulfuric acid, H_2SO_4 .

(a) Method

- Fill the burette with **FB 4**.
- Pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Rinse the 50 cm^3 measuring cylinder with distilled water.
- Use this measuring cylinder to add 20 cm^3 of **FB 5** into the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make 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 **FB 4** added in each accurate titration.

Keep FB 4 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FB 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **FB 3** required cm³ of **FB 4**. [1]

(c) Calculations

- (i) Calculate the number of moles of manganate(VII) ions present in the volume of **FB 4** recorded in (b).

moles of MnO_4^- = ... mol [1]

- (ii) Use your answer to (c)(i) and the equation on page 4 to determine the number of moles of hydrogen peroxide present in 25.0 cm³ of **FB 3**.

moles of H_2O_2 = ... mol [1]

- (iii) Calculate the concentration, in mol dm⁻³, of hydrogen peroxide in **FB 3**.

concentration of H_2O_2 = ... mol dm⁻³ [1]

- (d) In **Question 1** and in **Question 2** you determined the concentration of aqueous hydrogen peroxide using different methods. The method used in **Question 2** is the more accurate.

Identify **two** sources of error in the determination of the concentration in **Question 1** and suggest how these errors could be minimised.

error 1

minimised by

error 2

minimised by

[2]

- (e) A student suggested one source of error in the method used in **Question 2** was that the sulfuric acid was measured using a measuring cylinder and that a pipette should be used.

Explain whether this suggestion is correct.

.....

..... [1]

- (f) (i) Another student was given a sample of aqueous hydrogen peroxide that was labelled as '10 vol'.

The theoretical concentration of this sample of $\text{H}_2\text{O}_2(\text{aq})$ is $0.833 \text{ mol dm}^{-3}$.

The student used a titration method to find the actual concentration of this sample and found it to be $0.796 \text{ mol dm}^{-3}$.

Calculate the percentage difference, based on the theoretical concentration, between the actual and theoretical concentrations.

percentage difference = ... % [1]

- (ii) When determining the concentration of hydrogen peroxide in a school or college laboratory, the value is nearly always much lower than the theoretical value.

Suggest a reason for this difference.

.....

..... [1]

[Total:16]

Qualitative Analysis

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

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

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

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

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

No additional tests for ions present should be attempted.

3 (a) (i) FB 6, FB 7 and FB 8 are all aqueous solutions. Each contains one anion and one cation.

Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>		
	FB 6	FB 7	FB 8
To a 1 cm depth in a test-tube add a 1 cm depth of dilute sulfuric acid and then add a few drops of FB 4 , $\text{KMnO}_4(\text{aq})$.			
To a 1 cm depth in a boiling tube add aqueous sodium hydroxide, then			
warm gently.			
To a 1 cm depth in a test-tube add a 1 cm depth of FB 1 , $\text{H}_2\text{O}_2(\text{aq})$, and then add aqueous sodium hydroxide.			
To a 1 cm depth in a test-tube add aqueous barium chloride or aqueous barium nitrate.			
To a 1 cm depth in a boiling tube add a 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil and then warm gently.			

[8]

(ii) Identify, with a reason, the cation present in **FB 6**.

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

(iii) Identify, with a reason, **two** anions that **could** be present in **FB 6**.

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

(iv) Identify, with a reason, a cation that could **not** be present in **FB 7**.

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

(v) Identify, with a reason, an anion that could be present in **FB 8**.

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

(b) A student is given an unlabelled bottle containing a liquid that is either propan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$, or ethanoic acid, CH_3COOH .

Describe tests that would allow the student to confirm the identity of the liquid. Record in a suitable table the tests and the expected positive result for each of your tests.

[3]

[Total: 15]

Qualitative Analysis Notes

1 Reactions of aqueous cations

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

2 Reactions of anions

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	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, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

The Periodic Table of Elements

Group																											
1	2											1		13	14	15	16	17	18								
		Key																									
		atomic number atomic symbol name relative atomic mass																									
3	4																	5	6	7	8	9	10	11	12		
Li	Be																	B	C	N	O	F	Ne				
lithium	beryllium																	boron	carbon	nitrogen	oxygen	fluorine	neon				
6.9	9.0																	10.8	12.0	14.0	16.0	19.0	20.2				
11	12																	13	14	15	16	17	18				
Na	Mg																	Al	Si	P	S	Cl	Ar				
sodium	magnesium																	aluminium	silicon	phosphorus	sulfur	chlorine	argon				
23.0	24.3																	27.0	28.1	31.0	32.1	35.5	39.9				
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38								
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	39	40								
potassium	calcium	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton	41	42								
39.1	40.1	45.0	47.9	50.9	52.0	54.9	55.8	58.9	58.7	63.5	65.4	69.7	72.6	74.9	79.0	79.9	83.8	43	44								
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	45	46								
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	47	48								
rubidium	strontium	yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium	indium	tin	antimony	tellurium	iodine	xenon	49	50								
85.5	87.6	88.9	91.2	92.9	95.9	—	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3	51	52								
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	53	54								
Cs	Ba	lanthanoids	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	55	56								
caesium	barium		hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury	thallium	lead	bismuth	polonium	astatine	radon	57	58								
132.9	137.3		178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	—	—	—	59	60								
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	61	62								
Fr	Ra	actinoids	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	63	64								
francium	radium		rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	darmstadtium	roentgenium	copernicium	nihonium	flerovium	tennessine	livermorium	oganesson	—	65	66								
—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	67	68								

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	euroium	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	mendelevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—

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CHEMISTRY

9701/35

Paper 3 Advanced Practical Skills 1

October/November 2019

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.
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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 14 and 15.
A copy of the Periodic Table is printed on page 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	
Laboratory	

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1	
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Total	

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

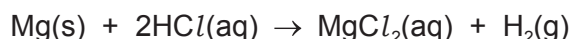


Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

- 1 In this experiment you will determine the concentration of a sample of hydrochloric acid. You will do this by measuring the volume of hydrogen produced when an excess of magnesium reacts with the acid.



FA 1 is magnesium powder, Mg.

FA 2 is hydrochloric acid, HCl.

(a) Method

- Weigh the container with **FA 1**. Record the mass.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm³ measuring cylinder completely with water. Hold a piece of paper towel firmly over the top, invert the measuring cylinder and place it in the water in the tub.
- Remove the paper towel and clamp the inverted measuring cylinder so that the open end is just above the base of the tub.
- Use the 25 cm³ measuring cylinder to place 25.0 cm³ of **FA 2** into the reaction flask, labelled **X**.
- Check that the bung fits tightly in the neck of flask **X**, clamp flask **X**, and place the end of the delivery tube into the inverted 250 cm³ measuring cylinder.
- Remove the bung from the neck of flask **X**. Tip all of **FA 1** into flask **X** and replace the bung **immediately**. Remove the flask from the clamp and swirl to mix the contents.
- Swirl the flask occasionally until no more gas is evolved. Replace the flask in the clamp.
- Measure and record the final volume of gas in the measuring cylinder.
- Weigh and record the mass of the container with any residual solid.
- Calculate and record the mass of **FA 1** used.

Keep FA 2 for use in Question 2.

[2]

(b) Calculations

- (i) Calculate the number of moles of hydrogen gas produced.
(Assume 1 mol of gas occupies 24.0 dm^3 at this temperature.)

moles of $\text{H}_2(\text{g}) = \dots\dots\dots \text{ mol}$
[1]

- (ii) Calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = $\dots\dots\dots \text{ mol dm}^{-3}$
[1]

- (iii) In this experiment the magnesium powder was in excess.

Calculate the mass of magnesium powder needed for complete reaction with all the hydrochloric acid in 25.0 cm^3 of **FA 2**.

mass of $\text{Mg} = \dots\dots\dots \text{ g}$
[1]

- (c) A student suggested two modifications to the method in (a) to give a more accurate value for the concentration.

For each suggestion, state whether you agree with the student and explain your answer.

Suggestion 1: Use magnesium ribbon rather than powdered magnesium; keep the rest of the experiment the same.

.....
.....

Suggestion 2: Use twice the mass of magnesium powder; keep the rest of the experiment the same.

.....
.....

[2]

- (d) Another student carried out the experiment in (a) but used less magnesium than that calculated in (b)(iii).

State and explain the effect this would have on the calculated concentration of hydrochloric acid in **FA 2**.

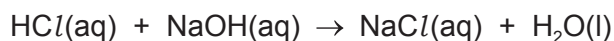
.....

.....

..... [1]

[Total: 8]

- 2 In this experiment you will determine the concentration of **FA 2** by titration using aqueous sodium hydroxide.



FA 2 is hydrochloric acid, HCl .

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

methyl orange indicator

(a) Method

Dilution of FA 2

- Fill the burette with **FA 2**.
- Run between 40.00 and 45.00 cm^3 from the burette into the 250 cm^3 volumetric flask.
- Record the volume used.
- Make the solution up to the 250 cm^3 mark by adding distilled water.
- Shake the flask thoroughly to ensure mixing.
- Label this solution of hydrochloric acid **FA 4**.

volume of **FA 2** used = ... cm^3

Titration

- Rinse the burette with distilled water and then with a little **FA 4**.
- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add several drops of methyl orange indicator.
- Perform a rough titration and record your burette readings.

The rough titre is cm^3 .

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

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

- (b) From your accurate titration results, obtain a value for the volume of **FA 4** to be used in your calculations. Show clearly how you obtained this value.

25.0 cm³ of **FA 3** required cm³ of **FA 4**.
[1]

(c) **Calculations**

- (i) Give your answers to (ii), (iii) and (iv) to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of hydrochloric acid that reacted with 25.0 cm³ of **FA 3**.

moles of HCl = ... mol
[1]

- (iii) Calculate the concentration of hydrochloric acid in **FA 4**.

concentration of HCl in **FA 4** = ... mol dm⁻³
[1]

- (iv) Calculate the concentration of hydrochloric acid in **FA 2**.

concentration of HCl in **FA 2** = ... mol dm⁻³
[1]

- (d) Calculate the maximum percentage error in the volume of **FA 2** you added to the volumetric flask.

maximum percentage error = ... %
[1]

- (e) In **Question 1** and **Question 2** you have determined the concentration of **FA 2** by two different methods. Each method used has possible sources of error, for example in **Question 1** the largest source of error is escape of gas.

Apart from this error, state and explain a source of error for each method.

Question 1

.....

Question 2

.....

[2]

[Total: 16]

Qualitative Analysis

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

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

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

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

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

No additional tests for ions present should be attempted.

3 (a) FA 5 is a salt that contains two different cations and a single anion from those listed in the Qualitative Analysis Notes.

- (i) Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat **gently**.
Do not inhale the fumes.
 Record **all** your observations.

.....

.....

.....

..... [2]

- (ii) Pour a 4 cm depth of distilled water into a boiling tube. Add the remaining **FA 5** and stir carefully until the solid has dissolved. This solution is **FA 6**.
 Carry out the following tests on **FA 6** and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth in a test-tube, add aqueous ammonia.	
To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then	
warm the mixture.	

<i>test</i>	<i>observations</i>
To a 1 cm depth in a test-tube, add aqueous barium nitrate or aqueous barium chloride, then	
add dilute hydrochloric acid or dilute nitric acid.	

[4]

(iii) Identify the three ions in **FA 5**.

FA 5 contains , ... and

[2]

- (b) A student carried out Qualitative Analysis tests on a hydrated salt, **FA 7**, and concluded that it contained the ions K^+ , Cr^{3+} and SO_4^{2-} .
The relative formula mass of **FA 7** is 499.3.

Determine the formula of **FA 7**.

The formula of **FA 7** is

[2]

Question 3 continues on page 10.

(c) **FA 8** is a solution containing a single cation and a single anion, both of which are listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

<i>test</i>	<i>observations</i>
To a 1 cm depth in a test-tube, add a few drops of aqueous acidified potassium manganate(VII), then	
add starch indicator.	
To a 1 cm depth in a test-tube, add aqueous sodium hydroxide.	

[2]

(ii) Identify the two ions in **FA 8**.

FA 8 contains and [1]

(iii) Suggest an additional test you could carry out to confirm the presence of the anion in **FA 8**.

Carry out this test and record your result.

[2]

(iv) Give the ionic equation for the reaction you carried out using **FA 8** and sodium hydroxide. Include state symbols.

..... [1]

[Total: 16]

Qualitative Analysis Notes

1 Reactions of aqueous cations

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

2 Reactions of anions

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	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, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

The Periodic Table of Elements

Group																	
1	2	1 H hydrogen 1.0														17	18
		Key															
		atomic number atomic symbol name relative atomic mass															
3	4																
Li lithium 6.9	Be beryllium 9.0																
11	12																
Na sodium 23.0	Mg magnesium 24.3																
19	20																
K potassium 39.1	Ca calcium 40.1																
37	38																
Rb rubidium 85.5	Sr strontium 87.6																
55	56																
Cs caesium 132.9	Ba barium 137.3																
87	88																
Fr francium —	Ra radium —																

lanthanoids																	
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	euroium	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	mendelevium	nobelium	lawrencium			
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—			

lanthanoids

actinoids

CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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CHEMISTRY

9701/36

Paper 3 Advanced Practical Skills 2

October/November 2019

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 14 and 15.
A copy of the Periodic Table is printed on page 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
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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



Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

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

- 1 Limewater is a saturated solution of calcium hydroxide, $\text{Ca}(\text{OH})_2$, in water. In this experiment you will determine the concentration of limewater by titration with hydrochloric acid.

FB 1 is limewater.

FB 2 is $0.500 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .
bromophenol blue indicator

(a) Method

Dilution of FB 2

- Pipette 25.0 cm^3 of **FB 2** into the 250 cm^3 volumetric flask.
- Make the solution up to the mark using distilled water.
- Shake the solution in the volumetric flask thoroughly.
- This solution of hydrochloric acid is **FB 3**. Label the volumetric flask **FB 3**.
- Rinse the pipette thoroughly.

Titration

- Fill the burette with **FB 3**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Add a few drops of bromophenol blue.
- Perform a **rough** titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record in a suitable form below all of your burette readings and the volume of **FB 3** added in each accurate titration.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

- (b) From your accurate titration results, obtain a suitable value for the volume of **FB 3** to be used in your calculations.
Show clearly how you obtained this value.

25.0 cm^3 of **FB 1** required cm^3 of **FB 3**. [1]

(c) Calculations

- (i) Give your answers to (ii), (iii), (iv) and (v) to the appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of hydrochloric acid, HCl , in the volume of **FB 3** calculated in (b).

moles of HCl = ... mol
[1]

- (iii) Give the equation for the reaction of calcium hydroxide with hydrochloric acid.

.....

Deduce the number of moles of calcium hydroxide that reacted with the hydrochloric acid in (c)(ii).

moles of $\text{Ca}(\text{OH})_2$ = ... mol
[1]

- (iv) Calculate the concentration, in mol dm^{-3} , of calcium hydroxide in **FB 1**.

concentration of $\text{Ca}(\text{OH})_2$ in **FB 1** = ... mol dm^{-3}
[1]

- (v) Calculate the mass of calcium hydroxide dissolved in 1.00 dm^3 of limewater, **FB 1**.

mass of $\text{Ca}(\text{OH})_2$ = ... g
[1]

[Total: 13]

- 2 In this experiment you will determine the enthalpy change, ΔH , for the decomposition of calcium hydroxide.



To do this, you will determine the enthalpy changes for the reactions of calcium hydroxide and calcium oxide with hydrochloric acid. Excess acid will be used for both experiments.

Then you will use Hess' Law to calculate the enthalpy change for the reaction.

FB 4 is calcium hydroxide, Ca(OH)_2 .

FB 5 is calcium oxide, CaO .

FB 6 is 2.50 mol dm^{-3} hydrochloric acid, HCl .

- (a) Determination of the enthalpy change for the reaction of calcium hydroxide, **FB 4**, with hydrochloric acid, **FB 6**

(i) **Method**

- Support a plastic cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 40 cm^3 of **FB 6** into the plastic cup.
- Measure and record the temperature of **FB 6**.
- Weigh the container with **FB 4**. Record the mass.
- Add all **FB 4** from the container to **FB 6** in the plastic cup.
- Stir constantly until the maximum temperature is reached.
- Measure and record the maximum temperature.
- Weigh and record the mass of the container with any residual solid.
- Calculate and record the mass of **FB 4** used.
- Calculate and record the temperature rise.

Keep FB 6 for use in Question 3.

Results

(ii) Calculations

Calculate the energy produced during this reaction.

(Assume that 4.2 J of heat energy changes the temperature of 1.0 cm³ of solution by 1.0 °C.)

energy produced = ... J [1]

(iii) Calculate the number of moles of calcium hydroxide, **FB 4**, used in the experiment.

moles of $\text{Ca(OH)}_2 = \dots\dots\dots \text{mol}$ [1]

(iv) Calculate the enthalpy change, in kJ mol^{-1} , for the reaction in which 1.00 mol of solid calcium hydroxide is neutralised by aqueous hydrochloric acid.

enthalpy change = ... kJ mol⁻¹
 sign *value*

[1]

- (c) Use your values for the enthalpy changes calculated in (a)(iv) and (b)(ii) to calculate the enthalpy change for the decomposition of calcium hydroxide.

Show clearly how you obtained your answer.

(If you were unable to calculate the enthalpy changes, assume that the magnitude of the enthalpy change in **(a)(iv)** is 164 kJ mol^{-1} and the magnitude in **(b)(ii)** is 191 kJ mol^{-1} .)

Note: these may not be the correct magnitudes and the signs have been deliberately omitted.)



enthalpy change = ... kJ mol⁻¹
 sign *value*

[2]

- (d) (i)** The experiment in **(b)** was repeated, using the same mass of calcium oxide, **FB 5**. However, 40 cm^3 of $3.0\text{ mol dm}^{-3}\text{ HCl}$ was used instead of 40 cm^3 of $2.5\text{ mol dm}^{-3}\text{ HCl}$.

How would the temperature rise compare with the one you obtained in **(b)(i)**? Explain your answer.

..... [1]

- (ii) A student suggested that the experiment in (a) would be more accurate if a taller plastic cup of the same diameter was used.

Do you agree with the student? Explain your answer.

..... [1]

[Total: 14]

Qualitative Analysis

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

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

- colour changes seen;
- the formation of any precipitate and its solubility in an excess of the reagent added;
- the formation of any gas and its identification by a suitable test.

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

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

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

No additional tests for ions present should be attempted.

- 3 (a) FB 7** is a solid containing one of the anions listed in the Qualitative Analysis Notes.
Place a small spatula measure of **FB 7** in a hard-glass test-tube.
Heat it gently at first and then more strongly. Identify the gas produced.
Leave the contents of the tube to cool.

Record **all** your observations.

.....

.....

.....

.....

.....

..... [3]

(b) **FB 8** and **FB 9** are both solutions of potassium compounds.
Each contains one anion which is listed in the Qualitative Analysis Notes.

(i) Carry out the following tests and record your observations.

<i>test</i>	<i>observations with FB 8</i>	<i>observations with FB 9</i>
To a 1 cm depth in a test-tube, add a few drops of aqueous acidified potassium manganate(VII).		
To a 1 cm depth in a test-tube, add an equal volume of dilute nitric acid followed by a few drops of aqueous barium nitrate, then		
add a few drops of aqueous silver nitrate.		
To a 1 cm depth in a boiling tube, add an equal volume of aqueous sodium hydroxide and warm carefully , then		
add a strip of aluminium foil.		

[5]

(ii) Give the ionic equation for the reaction of silver nitrate with **FB 8**. Include state symbols.

..... [1]

(iii) The reaction of aluminium with **FB 9** involves a redox reaction.

What species are oxidised and reduced in this reaction?

species oxidised

species reduced

[1]

- (c) (i) In a test-tube, mix together 1 cm depths of **FB 8** and **FB 9**. Record your observation.

observation

Then add **one drop** of **FB 6**, hydrochloric acid, and record your observation.

observation

[1]

- (ii) From your knowledge of **FB 8**, suggest the formula of the chemical you observed at the **end** of the experiment in (c)(i).

formula

[1]

- (iii) How would you test to confirm that the identification you made in (c)(ii) is correct?
Name the reagent you would use.
Carry out your test and record your observation.

reagent used

observation

[1]

[Total: 13]

Qualitative Analysis Notes

1 Reactions of aqueous cations

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

2 Reactions of anions

<i>ion</i>	<i>reaction</i>
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $\text{Cl}^-(\text{aq})$	gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$)
bromide, $\text{Br}^-(\text{aq})$	gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$)
iodide, $\text{I}^-(\text{aq})$	gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$)
nitrate, $\text{NO}_3^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
nitrite, $\text{NO}_2^-(\text{aq})$	NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil
sulfate, $\text{SO}_4^{2-}(\text{aq})$	gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}(\text{aq})$	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, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

The Periodic Table of Elements

Group																									
1	2											1		13	14	15	16	17	18						
														1 H hydrogen 1.0								2 He helium 4.0			

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	euroium	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	mendelevium	nobelium	lawrencium
—	232.0	231.0	238.0	—	—	—	—	—	—	—	—	—	—	—