Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

9942765474

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **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.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

1 You will determine the enthalpy change, ΔH, 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.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

FA 1 is hydrochloric acid, HCl.
FA 2 is magnesium ribbon, Mg.

(a) Method

- Weigh the **FA 2** and record the mass in the space below.
- Support the plastic cup in the 250 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 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 / °C									

time / minutes	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8
temperature / °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 °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 = ... °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^3 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 $kJ\,mol^{-1}$, when 1 mole of magnesium, **FA 2**, reacts with hydrochloric acid, **FA 1**.

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

[3]

(d) A student carried out the same procedure using the same concentration of sulfuric acid, H_2SO_4, 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.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

FA 3 is a diluted solution of **FA 1**, hydrochloric acid, HC*l*. **FA 3** was prepared by running 25.00 cm^3 of **FA 1** into a volumetric flask and adding distilled water until the total volume was 250.0 cm^3.
FA 4 is 0.100 mol dm^{-3} sodium hydroxide, NaOH.
bromophenol blue indicator

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 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 .... 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.

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 cm^3 of **FA 3** required .... 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^3 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^{-3}, of hydrochloric acid in **FA 1**.

concentration of HCl in **FA 1** = ... mol dm^{-3}

(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 ±0.06 cm^3 which gives a maximum percentage error of 0.24% for 25.0 cm^3 of **FA 3**.
The error in a single burette reading is ±0.05 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.

test	*observations*	
	FA 5	**FA 6**
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.

	FA 5	**FA 6**
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_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

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $Cl^-(aq)$	gives white ppt. with $Ag^+(aq)$ (soluble in $NH_3(aq)$)
bromide, $Br^-(aq)$	gives cream ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$)
iodide, $I^-(aq)$	gives yellow ppt. with $Ag^+(aq)$ (insoluble in $NH_3(aq)$)
nitrate, $NO_3^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil
nitrite, $NO_2^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (soluble in excess dilute strong acids)

3 Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (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

Key

atomic number
atomic symbol
name
relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
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	57–71 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 –	89–103 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 –		

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