Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

CHEMISTRY **9701/03**

Paper 3 Advanced Practical Skills **For examination from 2022**

SPECIMEN PAPER **2 hours**

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS
- Answer all questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION
- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [ ].

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages. Blank pages are indicated.

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 the precision of the apparatus you used in the data you record.

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

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, HC*l*.
FA 2 is magnesium ribbon, Mg. You should assume its mass is 0.19 g.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Coil **FA 2** so that it will fit into the bottom of the cup then remove it.
- Use the measuring cylinder to transfer 25.0 cm^3 of **FA 1** into the cup.
- Place the thermometer in the acid and, if necessary, tilt the cup so that the bulb of the thermometer is fully covered. Measure and 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 **FA 1** in the cup every half minute for $1\frac{1}{2}$ minutes.
- At time = 2 minutes carefully drop the coil of **FA 2** into the acid and stir the mixture.
- Record the temperature every half minute. Stir the mixture between thermometer readings.

Results

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								

[4]

(b) Plot a graph of temperature (on the *y*-axis) against time (on the *x*-axis) on the grid.
The scale for the *y*-axis should extend 10 °C above the maximum temperature you recorded.
Circle any points you consider to be anomalous.
You will use the graph to determine the theoretical maximum temperature rise at time = 2 minutes.

Draw two lines of best fit, the first for the temperature before adding **FA 2** and the second for the cooling of the mixture. Extrapolate both lines to 2 minutes and determine the theoretical rise in temperature at this time.

theoretical rise in temperature at 2 minutes = ... °C [4]

(c) **Calculations**

(i) Use your answer to **(b)** to calculate the energy change when **FA 2** is added to **FA 1**.
(Assume 4.2 J of energy changes the temperature of 1.0 cm^3 of the mixture by 1.0 °C.)

energy change = ... J [1]

(ii) Use your answer to **(c)(i)** to calculate the enthalpy change, ΔH, in kJ mol^{-1}, when 1 mol of magnesium, **FA 2**, reacts with hydrochloric acid, **FA 1**.

ΔH = …… .... kJ mol^{-1}
(sign) (value) [2]

(d) A student repeats the procedure, but instead of hydrochloric acid, uses sulfuric acid, H_2SO_4, of the same concentration. The student predicts that the enthalpy change will be twice the value of the enthalpy change with hydrochloric acid.

Explain whether the student's prediction is correct.

....

.... [1]

(e) The enthalpy change determined in **(c)(ii)** is **not** accurate.

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

improvement ....

explanation ....

....
[1]

[Total: 13]

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

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

FA 3 is a diluted solution of **FA 1**, HC*l*. **FA 3** was prepared by diluting 10.0 cm^3 of **FA 1** to 250 cm^3 with distilled water.
FA 4 is a solution containing 1.25 g Na_2CO_3 in each 250 cm^3.
The indicator is bromophenol blue.

(a) Method

- Fill a burette with **FA 3**.
- Use the pipette to transfer 25.0 cm^3 of **FA 4** into a conical flask.
- Add approximately 10 drops of bromophenol blue.
- Carry out 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 **FA 3** added in each accurate titration.

[7]

(b) Calculate the mean titre of **FA 3**. Show clearly how you obtained this value.

Mean titre of **FA 3** = ... cm^3. [1]

(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to an appropriate number of significant figures. [1]

(ii) Calculate the number of moles of sodium carbonate present in 25.0 cm^3 of **FA 4**.

moles of Na_2CO_3 in 25.0 cm^3 of **FA 4** = ... mol [1]

(iii) Calculate the concentration, in mol dm^{-3}, of hydrochloric acid in **FA 3**.

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

concentration of HC*l* in **FA 3** = ... mol dm^{-3} [1]

(iv) Calculate the concentration of hydrochloric acid in **FA 1**.

concentration of HC*l* in **FA 1** = ... mol dm^{-3} [1]

(v) Show, by calculation, that the amount of hydrochloric acid used in **Question 1(a)** was in excess of the amount of magnesium used.

[1]

[Total: 13]

Qualitative analysis

For each test you should record **all** your observations in the spaces provided.

Examples of observations include:

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

You should record clearly at what stage in a test an observation is made.

Where no change is observed you should write 'no change'.

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

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

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

No additional tests should be attempted.

3 (a) **FA 5** is a salt containing three ions all of which are listed in the Qualitative analysis notes.

Place a small spatula measure of **FA 5** in a hard-glass test-tube and heat for no longer than one minute. Record **all** your observations.

....

....

....

....

.... [3]

(b) **FA 6** is an aqueous solution of **FA 5**.
FA 7 is an aqueous solution of a salt containing two ions.

Carry out the tests and record your observations in Table 3.1.

Table 3.1

test	*observations*	
	FA 6	**FA 7**
Test 1 To a 0.5 cm depth of solution in a boiling tube add aqueous sodium hydroxide, then		
warm gently.		
Allow to cool, add a piece of aluminium foil and warm again.		
Test 2 To a 1 cm depth of solution in a test-tube add 2 or 3 drops of aqueous acidified potassium manganate(VII).		
Test 3 To a 1 cm depth of solution in a test-tube add a 2 cm depth of aqueous hydrogen peroxide, then		
leave to stand for about a $\frac{1}{2}$ minute.		
Test 4 To a 1 cm depth of solution in a test-tube add 2 or 3 drops of aqueous barium chloride or aqueous barium nitrate, then		
add a 1 cm depth of dilute nitric acid. Wash the test-tubes after use.		

[7]

(c) Identify as many ions present in **FA 6** and **FA 7** as possible from your observations in **(a)** and **(b)**.

Write the formulae of the ions in Table 3.2. If an ion cannot be positively identified from the tests, write 'unknown' in the space.

Table 3.2

	cations	anions
FA 6		
FA 7		

[3]

(d) Write an ionic equation for a precipitation reaction occurring in **(b)**. Include state symbols.

.... [1]

[Total: 14]

Qualitative analysis notes

1 Reactions of cations

cation	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 warming	–
barium, Ba^{2+}(aq)	faint white ppt. is observed unless [Ba^{2+}(aq)] is very low	no ppt.
calcium, Ca^{2+}(aq)	white ppt. unless [Ca^{2+}(aq)] is very low	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	pale 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

anion	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 / off-white ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives pale 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; decolourises acidified aqueous $KMnO_4$
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca^{2+}(aq)]
sulfite, SO_3^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids); decolourises acidified aqueous $KMnO_4$
thiosulfate, $S_2O_3^{2-}$(aq)	gives white ppt. slowly with H^+

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
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

4 Tests for elements

element	test and test result
iodine, I_2	gives blue-black colour on addition of starch solution

Important values, constants and standards

molar gas constant	$R = 8.31\ J\ K^{-1}\ mol^{-1}$
Faraday constant	$F = 9.65 \times 10^4\ C\ mol^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\ mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\ C$
molar volume of gas	$V_m = 22.4\ dm^3\ mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\ dm^3\ mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\ mol^2\ dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\ kJ\ kg^{-1}\ K^{-1}$ ($4.18\ J\ g^{-1}\ K^{-1}$)

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 –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

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 –