



Cambridge International AS & A Level

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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 [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

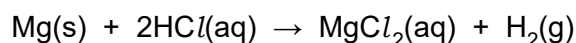
Quantitative analysis

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.



FA 1 is hydrochloric acid, HCl.

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

(a) Method

- Support the cup in the 250 cm³ 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 cm³ 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 1½ 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.

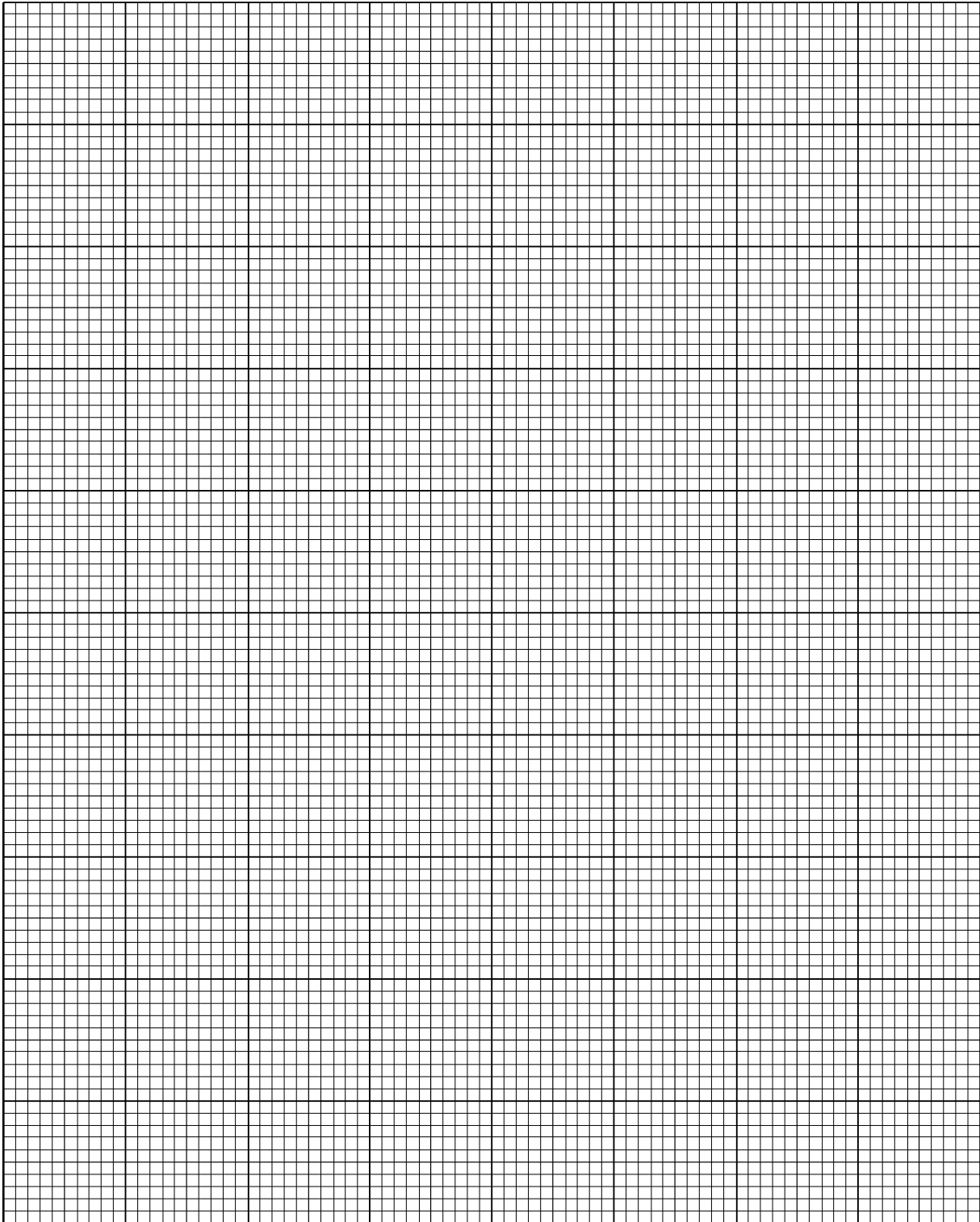
Results

time / minutes	0	½	1	1½	2	2½	3	3½	4
temperature / °C					X				

time / minutes	4½	5	5½	6	6½	7	7½	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 $10\text{ }^{\circ}\text{C}$ 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 = $^{\circ}\text{C}$ [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 cm³ 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**.

$\Delta H = \dots\dots\dots$ kJ mol⁻¹
(sign) (value) [2]

- (d) A student repeats the procedure, but instead of hydrochloric acid, uses sulfuric acid, H₂SO₄, 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.

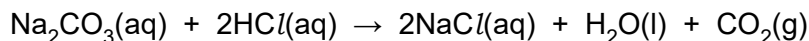
improvement

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.



FA 3 is a diluted solution of **FA 1**, HCl . **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 $1.25 \text{ g Na}_2\text{CO}_3$ 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]

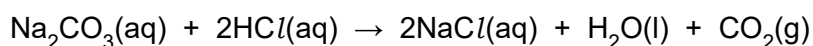
(c) Calculations

(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 cm³ of **FA 4**.

moles of Na₂CO₃ in 25.0 cm³ of **FA 4** = mol [1]

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



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

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

concentration of HCl 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.

.....

.....

.....

.....

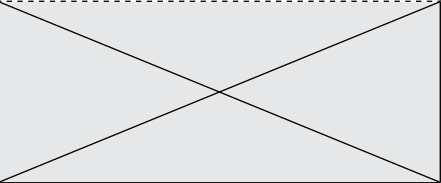
.....

..... [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

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
<p>Test 1 To a 0.5 cm depth of solution in a boiling tube add aqueous sodium hydroxide, then</p> <hr style="border-top: 1px dashed black;"/> <p>warm gently.</p> <hr style="border-top: 1px dashed black;"/> <p>Allow to cool, add a piece of aluminium foil and warm again.</p>		
<p>Test 2 To a 1 cm depth of solution in a test-tube add 2 or 3 drops of aqueous acidified potassium manganate(VII).</p>		
<p>Test 3 To a 1 cm depth of solution in a test-tube add a 2 cm depth of aqueous hydrogen peroxide, then</p> <hr style="border-top: 1px dashed black;"/> <p>leave to stand for about a $\frac{1}{2}$ minute.</p>		
<p>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</p> <hr style="border-top: 1px dashed black;"/> <p>add a 1 cm depth of dilute nitric acid. Wash the test-tubes after use.</p>		

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

The Periodic Table of Elements

		Group																																	
1	2															13	14	15	16	17	18														
		Key																																	
		atomic number atomic symbol name relative atomic mass																																	
		1 H hydrogen 1.0																																	
		2 He helium 4.0																																	
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																				
Li lithium 6.9	Be beryllium 9.0	B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2	Na sodium 23.0	Mg magnesium 24.3	Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9																				
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36										
K potassium 39.1	Ca calcium 40.1	Sc scandium 45.0	Ti titanium 47.9	V vanadium 50.9	Cr chromium 52.0	Mn manganese 54.9	Fe iron 55.8	Co cobalt 58.9	Ni nickel 58.7	Cu copper 63.5	Zn zinc 65.4	Ga gallium 69.7	Ge germanium 72.6	As arsenic 74.9	Se selenium 79.0	Br bromine 79.9	Kr krypton 83.8	Rb rubidium 85.5	Sr strontium 87.6	Y yttrium 88.9	Zr zirconium 91.2	Nb niobium 92.9	Mo molybdenum 95.9	Tc technetium —	Ru ruthenium 101.1	Rh rhodium 102.9	Pd palladium 106.4	Ag silver 107.9	Cd cadmium 112.4	In indium 114.8	Sn tin 118.7	Sb antimony 121.8	Te tellurium 127.6	I iodine 126.9	Xe xenon 131.3
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Cs caesium 132.9	Ba barium 137.3	lanthanoids	Hf hafnium 178.5	Ta tantalum 180.9	W tungsten 183.8	Re rhenium 186.2	Os osmium 190.2	Ir iridium 192.2	Pt platinum 195.1	Au gold 197.0	Hg mercury 200.6	Tl thallium 204.4	Pb lead 207.2	Bi bismuth 209.0	Po polonium —	At astatine —	Rn radon —	Fr francium —	Ra radium —	actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganesson —

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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