

# Cambridge International AS & A Level

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	CENTRE NUMBER		CANDIDATE NUMBER	
ω	CHEMISTRY			9701/31
ω	Paper 3 Advanc	ed Practical Skills 1	Octob	oer/November 2024
ο ω				2 hours
* 3 2 3 0 6 3 7 4 3	You must answe	er on the question paper.		

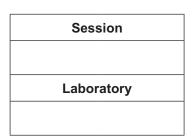
You will need: The materials and apparatus listed in the confidential instructions

#### 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.



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Total		

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IV [4]



### Quantitative analysis

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

2

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 The neutralisation of an acid by an alkali is an exothermic reaction. The concentration of an acid can be found by measuring the temperature change when the acid reacts with an alkali.

You will determine the concentration of sulfuric acid by adding aqueous sodium hydroxide of known concentration to the sulfuric acid and measuring the temperature change.

**FA 1** is 2.01 mol dm<sup>-3</sup> sodium hydroxide, NaOH. **FA 2** is sulfuric acid,  $H_2SO_4$ .

- (a) Method
  - Support the cup in the 250 cm<sup>3</sup> beaker.
  - Pipette  $25.0 \text{ cm}^3$  of **FA 1** into the cup.
  - Place the thermometer into the **FA 1** in the cup. Tilt the cup if necessary to ensure the bulb of the thermometer is fully covered. Record the temperature of **FA 1** in Table 1.1. This is the temperature when the volume of **FA 2** is 0.00 cm<sup>3</sup>.
  - Fill the burette with **FA 2**.
  - Run 5.00 cm<sup>3</sup> of **FA 2** into the cup containing **FA 1**.
  - Stir the mixture and record the maximum temperature in Table 1.1.
  - Run further 5.00 cm<sup>3</sup> portions of **FA 2** into the same cup.
  - After each addition of **FA 2** stir the contents of the cup. Record the maximum temperature for each addition.

total volume of <b>FA 2</b> /cm <sup>3</sup>	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
temperature /°C									

#### Table 1.1

Keep the rest of FA 2 for use in Question 2.

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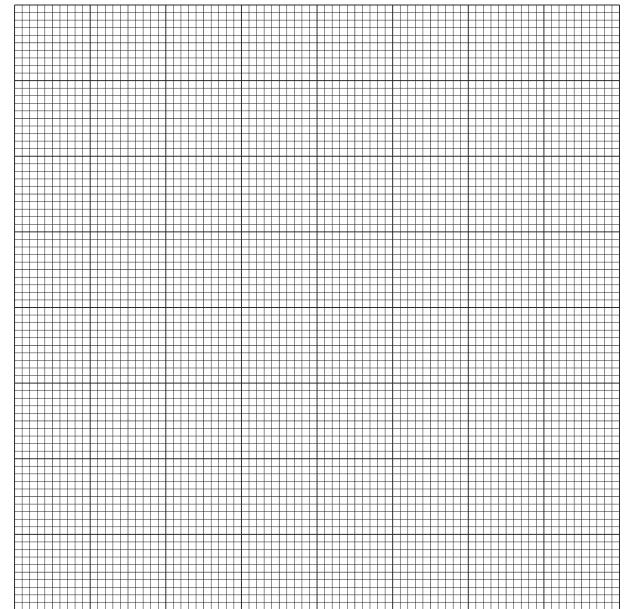
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(b) Plot a graph of temperature of solution (*y*-axis) against total volume of **FA 2** added (*x*-axis) on the grid. Select a scale for the *y*-axis to include a value 3 °C above your maximum temperature reading. Label any points you consider to be anomalous.

3

Draw **two** lines of best fit through the points on your graph. Draw the first line for the increase in temperature and the second line after the maximum temperature was reached. Extrapolate the lines so they intersect. This intersection corresponds to the volume of **FA 2** needed to neutralise the **FA 1** in your experiment in **(a)**.





25.0 cm<sup>3</sup> of **FA 1** required .....cm<sup>3</sup> of **FA 2**. [5]

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(c) (i) Calculate the amount, in mol, of sodium hydroxide, **FA 1**, pipetted into the cup.

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amount of NaOH = .....mol [1]

(ii) The equation for this neutralisation reaction is shown.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(I)$$

Calculate the concentration, in mol dm<sup>-3</sup>, of sulfuric acid in **FA 2**.

Show your working.

concentration of  $H_2SO_4 = \dots mol dm^{-3}$ [2]

[Total: 12]

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Acids react with carbonates to produce carbon dioxide gas. 2

 $Na_2CO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(I)$ 

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This reaction can be used to determine the concentration of acid, using the mass of carbon dioxide released.

You will determine the concentration of sulfuric acid in FA 2.

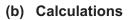
FA 2 is the solution used in Question 1.

**FA 3** is sodium carbonate,  $Na_2CO_3$ .

## (a) Method

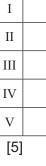
- Use the 25 cm<sup>3</sup> measuring cylinder to transfer 25.0 cm<sup>3</sup> of **FA 2** into the conical flask.
- Weigh the flask with the acid. Record the mass.
- Weigh the container with FA 3. Record the mass.
- Carefully tip all of FA 3 into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand with occasional swirling until the fizzing stops.
- Weigh the container with any residual FA 3. Record the mass.
- Calculate and record the mass of FA 3 added to the flask.
- Calculate and record the total mass of flask + acid + FA 3.
- Weigh the flask and contents when the fizzing has stopped. Record the mass.
- Calculate and record the mass of carbon dioxide given off during the experiment.

# Results



Calculate the amount, in mol, of carbon dioxide given off in the reaction. (i)







(ii) The sodium carbonate, **FA 3**, was in excess in the reaction with sulfuric acid. Show by calculation that the sodium carbonate was in excess. Use your answer to (b)(i).

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[2]

Calculate the concentration, in mol dm<sup>-3</sup>, of sulfuric acid in FA 2. (iii)

concentration of  $H_2SO_4$  = ..... moldm<sup>-3</sup> [1]

A student does not have a conical flask and uses a small beaker for the reaction. Explain (c) (i) why a conical flask is better.

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

Two students made suggestions of how they thought the experiment in (a) could be (ii) adapted to determine the concentration of sulfuric acid, FA 2, by using other reactions. In each case their teacher told them that this method was not suitable.

Explain, in each case, why the method is **not** suitable. Do **not** consider factors based on quantities of any reagent.

Student 1 suggested using magnesium in place of sodium carbonate.

Student 2 suggested using calcium carbonate in place of sodium carbonate.

.....





[3]





(d) State the uncertainty in a single reading of your balance.

uncertainty = ± .....g

Calculate the maximum percentage error in the mass of FA 3 that you weighed out in (a).

8

maximum percentage error = ...... % [1]

[Total: 14]

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#### **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. If a solid is heated, a hard-glass test-tube must be used.

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

No additional tests should be attempted.

- 3 FA 4, FA 5 and FA 6 are compounds of the same metal in different oxidation states.
  - (a) (i) Place a small spatula measure of **FA 4** in a hard-glass test-tube. Heat the tube gently at first and then more strongly.

Record all your observations.

Leave the tube and contents to cool and keep for use in (a)(iii).





(ii) Dissolve a **small** spatula measure of **FA 4** in approximately 5 cm depth of distilled water in a boiling tube and add approximately 1 cm depth of dilute sulfuric acid.

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

### Table 3.1

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test	observations
<b>Test 1</b> To a 1 cm depth of aqueous <b>FA 4</b> in a test-tube add aqueous iron(II) sulfate.	
<b>Test 2</b> To a 1 cm depth of aqueous <b>FA 4</b> in a test-tube add hydrogen peroxide.	

(iii) To the cooled test-tube in (a)(i) add a 5 cm depth of distilled water. Observe and record the colour formed.

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 Ľ	1	



[2]



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(b) Dissolve a small spatula measure of **FA 5** in a boiling tube half-filled with distilled water. Warming may be needed to dissolve the **FA 5**.

Carry out the following tests and record your observations in Table 3.2.

For each of the tests use a 1 cm depth of this **FA 5** solution in a test-tube.

#### Table 3.2

test	observations
Test 1 Add dilute nitric acid, then	
add aqueous silver nitrate.	
Test 2   Add aqueous barium chloride or   barium nitrate, then	
add dilute nitric acid.	
Test 3   Add aqueous sodium hydroxide, then	
add hydrogen peroxide.	



[Turn over



(c) Carry out the following tests and record your observations in Table 3.3. Identify any gases produced.

For each of the tests use a small spatula measure of **FA 6** in a test-tube.

#### Table 3.3

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test	observations and gases produced
<b>Test 1</b> Add a 1 cm depth of dilute nitric acid.	
Test 2Add a few drops of concentratedhydrochloric acid.CARE Hydrochloric acid is corrosive.Fill the test-tube with water as soon asyou have made your observation.	
<b>Test 3</b> Add a 1 cm depth of hydrogen peroxide.	

(d) (i) Use your observations from the tests on FA 4, FA 5 and FA 6 to suggest the identity of the metal present in all 3 compounds.

Metal identity .....

- (ii) Identify the oxidation state of the metal in each compound.
  - FA 4 ..... FA 5 .....
  - FA 6 .....

[2]

[3]

[1]

[Total: 14]





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# Qualitative analysis notes

# 1 Reactions of cations

cation	reactio	on with	
	NaOH(aq)	NH <sub>3</sub> (aq)	
aluminium, Al <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess	
ammonium, NH <sub>4</sub> +(aq)	no ppt. ammonia produced on warming	-	
barium, Ba <sup>2+</sup> (aq)	faint white ppt. is observed unless [Ba <sup>2+</sup> (aq)] is very low	no ppt.	
calcium, Ca <sup>2+</sup> (aq)	white ppt. unless [Ca <sup>2+</sup> (aq)] is very low	no ppt.	
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess	
copper(II), Cu <sup>2+</sup> (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution	
iron(II), Fe <sup>2+</sup> (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 <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess	
magnesium, Mg <sup>2+</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess	
manganese(II), Mn <sup>2+</sup> (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 <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess	

#### 2 Reactions of anions

anion	reaction
carbonate, CO <sub>3</sub> <sup>2-</sup>	CO <sub>2</sub> liberated by dilute acids
chloride, Cl <sup>-</sup> (aq)	gives white ppt. with $Ag^+(aq)$ (soluble in $NH_3(aq)$ )
bromide, Br <sup>–</sup> (aq)	gives cream/off-white ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$ )
iodide, I <sup>_</sup> (aq)	gives pale yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq))
nitrate, NO <sub>3</sub> <sup>-</sup> (aq)	$NH_3$ liberated on heating with $OH^-(aq)$ and $Al$ foil
nitrite, NO <sub>2</sub> <sup>-</sup> (aq)	NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and A <i>l</i> foil; decolourises acidified aqueous KMnO <sub>4</sub>
sulfate, SO <sub>4</sub> <sup>2–</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca <sup>2+</sup> (aq)]
sulfite, SO <sub>3</sub> <sup>2–</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO <sub>4</sub>
thiosulfate, S <sub>2</sub> O <sub>3</sub> <sup>2–</sup> (aq)	gives off-white/pale yellow ppt. slowly with H <sup>+</sup>



#### 3 **Tests for gases**

gas	test and test result
ammonia, NH <sub>3</sub>	turns damp red litmus paper blue
carbon dioxide, CO <sub>2</sub>	gives a white ppt. with limewater
hydrogen, H <sub>2</sub>	'pops' with a lighted splint
oxygen, O <sub>2</sub>	relights a glowing splint

#### **Tests for elements** 4

element	test and test result
iodine, I <sub>2</sub>	gives blue-black colour on addition of starch solution

### Important values, constants and standards

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

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		18	2	He	helium 4.0	10	Ne	neon 20.2	18	Ar	argon 39.9	36	Кr	krypton 83.8	54	Xe	xenon 131.3	86	Rn	radon -	118	Og	oganesson
		17				6	ш	fluorine 19.0	17	Cl	chlorine 35.5	35	Ŗ	bromine 79.9	53	Ι	iodine 126.9	85	At	astatine -	117	Ъ	tennessine
		16				8	0	oxygen 16.0	16	S	sulfur 32.1	34	Se	selenium 79.0	52	Те	tellurium 127.6	84	Ро	polonium –	116	۲	livermorium
		15				7	z	nitrogen 14.0	15	۵.	phosphorus 31.0	33	As	arsenic 74.9	51	Sb	antimony 121.8	83	Ē	bismuth 209.0	115	Mc	moscovium
		14				9	ပ	carbon 12.0	14	Si	silicon 28.1	32	Ge	germanium 72.6	50	Sn	tin 118.7	82	Pb	lead 207.2	114	Fl	flerovium
		13				5	В	boron 10.8	13	Al	aluminium 27.0	31	Ga	gallium 69.7	49	In	indium 114.8	81	11	thallium 204.4	113	ЧN	nihonium
											12	30	Zn	zinc 65.4	48	Сd	cadmium 112.4	80	Hg	mercury 200.6	112	C	copernicium
ements											11	29	Cu	copper 63.5	47	Ag	silver 107.9	79	Au	gold 197.0	111	Rg	roentgenium
The Periodic Table of Elements	Group										10	28	ïZ	nickel 58.7	46	Pd	palladium 106.4	78	Ę	platinum 195.1	110	Ds	darmstadtium
riodic Ta	Gro										6	27	ပိ	cobalt 58.9	45	RЪ	rhodium 102.9	77	Ir	iridium 192.2	109	Mt	meitnerium
The Per			-	т	hydrogen 1.0						8	26	Ъe	iron 55.8	44	Ru	ruthenium 101.1	76	Os	osmium 190.2	108	Hs	hassium

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atomic symbol relative atomic mass

atomic number Key

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	57	22 C	<b>6</b> 20	09	<sup>61</sup>	62 <b>C</b> 22	63	τ 0	65 T D	99	67 LLA	68 7	60 <b>K</b>	70 VD	71
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	lanthanum	cerium	praseodymium		promethium	samarium	europium	gadolinium	terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
	138.9	140.1	140.9	144.2	I	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
	89	06	91	92	93	94	95	96	97	98	66	100	101	102	103
	Ac	Тh	Ра		dN	Pu	Am	Cm	¥	ç	Es	E	рМ	No	Ļ
	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium	lawrencium
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