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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

* 4 6 6 8 1 7 4 8 7 3 *

CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **May/June 2025**

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 **16** pages. Any blank pages are indicated.

DC (PQ) 338072/3

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 percentage purity of a sample of calcium carbonate by reacting it with excess hydrochloric acid and measuring the volume of carbon dioxide produced.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

FA 1 is impure calcium carbonate, $CaCO_3$.
FA 2 is 0.500 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Weigh the container with **FA 1**. Record the mass in the space for results.
- Fill the tub with water to a depth of approximately 5 cm.
- Fill the 250 cm^3 measuring cylinder completely with water. Holding 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 the open end is in the water just above the base of the tub.
- Using the 50 cm^3 measuring cylinder, transfer 50.0 cm^3 of **FA 2** into the 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 inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip all of the **FA 1** into the acid in the flask and replace the bung **immediately**. Remove the flask from the clamp and swirl it to mix the contents.
- Replace the flask in the clamp and leave until the fizzing stops. Swirl the flask occasionally.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** that is added to the acid.
- When no more gas is collected, record the final volume of gas.

You may wish to start Question 2 or Question 3 while the gas is being collected.

Results

I	
II	
III	

[3]

(b) Calculations

(i) Calculate the amount, in mol, of carbon dioxide collected in the measuring cylinder (at room conditions).

amount of CO_2 = ... mol

Hence, deduce the amount, in mol, of calcium carbonate present in the **FA 1** used.

amount of $CaCO_3$ = ... mol
[1]

(ii) Use your answer to **(b)(i)** and the mass of **FA 1** used to calculate the percentage purity of calcium carbonate. Show your working.

purity of calcium carbonate = ... % [1]

(c) A student carries out the experiment described in **(a)** using 25.0 cm^3 of 1.00 $mol\,dm^{-3}$ hydrochloric acid. The mass of **FA 1** is **not** changed.

Suggest the consequence of this change on the percentage purity of calcium carbonate calculated by placing **one** tick (✓) in Table 1.1.

Table 1.1

The percentage purity calculated would increase.	
The percentage purity calculated would stay the same.	
The percentage purity calculated would decrease.	

Explain your answer.

....

....

....

....
[2]

(d) The student repeats the method in **(a)** but the hydrochloric acid is **not** used in excess.

(i) State an observation that shows that the acid is **not** used in excess.

.... [1]

(ii) Explain what effect, if any, this would have on the percentage purity of calcium carbonate calculated in **(b)(ii)**.

....

....

.... [2]

[Total: 10]

2 You will determine the percentage purity of another sample of calcium carbonate, $CaCO_3$, by titration.

The experiment involves three steps.

step 1 A known mass of the same impure calcium carbonate, **FA 1**, is reacted with an excess of hydrochloric acid to form **FA 3**. This step has been done for you.
step 2 You will dilute the products of step 1 to a known volume.
step 3 You will carry out a titration to find out how much acid remains after the reaction in step 1.

FA 3 has been prepared by reacting 19.0 g of **FA 1** with 250 cm^3 of 2.00 mol dm^{-3} hydrochloric acid, HCl.
FA 5 is 0.0900 mol dm^{-3} sodium hydroxide, NaOH.
FA 6 is bromophenol blue indicator.

(a) Method

step 2

- Pipette 25.0 cm^3 of **FA 3** into the 250 cm^3 volumetric flask.
- Make the solution up to 250 cm^3 with distilled water.
- Thoroughly mix the contents of the volumetric flask. This solution is **FA 4**.

step 3

- Fill the burette with **FA 5**.
- Rinse the pipette with distilled water and then with **FA 4**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add several drops of **FA 6**.
- 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 in the space below, all your burette readings and the volume of **FA 5** added in each accurate titration.

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FA 4** required .... cm^3 of **FA 5**. [1]

(c) Calculations

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

(ii) Calculate the amount, in mol, of sodium hydroxide in the volume of **FA 5** in **(b)**.

amount of NaOH = ... mol [1]

(iii) Use your answer to **(c)(ii)** to calculate the amount, in mol, of hydrochloric acid in 250 cm^3 of **FA 4**.

amount of HCl in 250 cm^3 of **FA 4** = ... mol

Hence, calculate the amount, in mol, of hydrochloric acid present in 250 cm^3 of **FA 3**.

amount of HCl in 250 cm^3 of **FA 3** = ... mol [1]

(iv) Calculate the amount, in mol, of hydrochloric acid used to prepare **FA 3**.

amount of HCl = ... mol [1]

(v) Use your answers to **(c)(iii)** and **(c)(iv)** to calculate the amount, in mol, of hydrochloric acid that reacted with the **FA 1** in step 1.

amount of HCl that reacted with **FA 1** = ... mol [1]

(vi) Use your answer to **(c)(v)** to calculate the amount, in mol, of calcium carbonate present in **FA 1**.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

amount of $CaCO_3$ in **FA 1** = ... mol [1]

(vii) Use your answer to **(c)(vi)** and the mass of **FA 1** used to calculate the percentage purity of calcium carbonate. Show your working.

purity of calcium carbonate = ... % [1]

(d) The percentage purity of calcium carbonate in **FA 1** has been determined by two different methods, gas collection and titration. The gas collection method used in Question 1 is **less** accurate.

(i) Suggest **two** reasons why the gas collection method is less accurate.

1 ....

....

2 ....

....
[2]

(ii) Describe a change to the gas collection method that would improve the accuracy of the percentage purity determined in Question 1.

....

....

.... [1]

[Total: 18]

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 (a) **FA 7** is a solution containing two cations and one anion. All of the ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests and record your observations in Tables 3.1 and 3.2. For each test use a 1 cm depth of **FA 7** in a test-tube unless the solution requires heating.

Table 3.1

test	*observations*
Test 1 Add aqueous ammonia.	
Test 2 To a 1 cm depth of **FA 7** in a boiling tube, add aqueous sodium hydroxide, then	
warm the mixture carefully.	
Test 3 Add a few drops of silver nitrate.	

Table 3.2

test	*observations*
Test 4 Add a 1 cm depth of aqueous barium chloride or aqueous barium nitrate.	
Test 5 Add a 1 cm depth of dilute nitric acid, then	
leave to stand for a few minutes.	
Test 6 Add a 1 cm depth of aqueous potassium iodide, then	
add a few drops of starch solution.	

[5]

(ii) Write an ionic equation for a reaction in **(a)(i)** that resulted in the formation of a precipitate. Include state symbols.

.... [1]

(iii) Give the formula of each ion present in **FA 7**. If you cannot identify an ion, write 'unknown.'

cations .... and ....

anion ....

[2]

(b) **FA 8** is an anhydrous sodium compound.

(i) Transfer a spatula measure of **FA 8** to a hard-glass test-tube. Heat the test-tube gently at first, then more strongly until no further change occurs. Record your observations.

....

.... [1]

(ii) The **FA 9** provided is a sample of the residue obtained from heating **FA 8**.
To a 2 cm depth of nitric acid in a test-tube, slowly add a small spatula measure of **FA 9**.
Record your observations.

....

....

.... [2]

(iii) Deduce the formula of **FA 8**.

FA 8 is .... [1]

[Total: 12]

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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 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	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,mol^{-1}$
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	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

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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 144.2	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 –