Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

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CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **October/November 2021**

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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

Session
Laboratory

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.
- Notes for use in qualitative analysis are provided in the question paper.

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages. Any blank pages are indicated.

[Turn over

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

1 You will investigate a compound of a Group 1 element to determine which element is present. Group 1 carbonates decompose to give carbon dioxide when heated to high temperatures.

$$\mathbf{X}_2CO_3(s) \rightarrow \mathbf{X}_2O(s) + CO_2(g)$$

FA 1 is the carbonate of the element, $\mathbf{X}_2CO_3$.

(a) Method

- Weigh a crucible with its lid and record the mass.
- Add 1.40–1.60 g of **FA 1** to the crucible.
- Weigh the crucible and its lid with **FA 1** and record the mass.
- Place the crucible on the pipe-clay triangle. Heat the crucible, with its lid on, gently for approximately 1 minute. Then heat strongly for another minute.
- Carefully remove the lid. Heat the crucible strongly for 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

While the crucible is cooling you may wish to begin work on Question 2.

- Reweigh the crucible and contents with its lid. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further 2 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes. Reweigh the crucible and residue with its lid. Record the mass.
- Calculate and record the mass of **FA 1** added to the crucible. Calculate the mass of residue obtained.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

(i) Calculate the mass of carbon dioxide produced when the sample of $\mathbf{X}_2CO_3$ was heated.

mass of CO_2 produced = ... g [1]

(ii) Calculate the number of moles of $\mathbf{X}_2CO_3$ needed to produce the mass of carbon dioxide calculated in **(b)(i)**.

moles of $\mathbf{X}_2CO_3$ needed = ... mol [1]

(iii) Use your answer to **(b)(ii)** and the information on page 2 to calculate the relative formula mass, M_r, of $\mathbf{X}_2CO_3$.

M_r of $\mathbf{X}_2CO_3$ = ... [1]

(iv) Use your answer to **(b)(iii)** to calculate the relative atomic mass, A_r, of **X**. Hence identify **X**. Explain how you reached your conclusion.

X is ..... .

.....

..... [2]

(c) In this experiment you heated the sample of $\mathbf{X}_2CO_3$ for approximately 8 minutes.

Explain, using evidence from your results in **(a)**, whether your sample of $\mathbf{X}_2CO_3$ had decomposed completely.

.....

..... [1]

[Total: 11]

[Turn over

2 In this experiment you will titrate a solution of the hydroxide of a Group 1 element, **Z**, with sulfuric acid. The equation for the reaction is shown.

Z may or may not be the same as **X**.

$$2\mathbf{Z}OH(aq) + H_2SO_4(aq) \rightarrow \mathbf{Z}_2SO_4(aq) + 2H_2O(l)$$

FA 2 is 26.3 g dm^{-3} aqueous hydroxide of metal **Z**, **Z**OH.
FA 3 is 0.0500 mol dm^{-3} sulfuric acid, H_2SO_4.
bromophenol blue indicator

(a) Method

- Pipette 25.0 cm^3 of **FA 2** into the 250 cm^3 volumetric flask.
- Add distilled water to the flask to make 250 cm^3 of solution. Shake the flask thoroughly to ensure complete mixing. Label this solution **FA 4**.
- Rinse the pipette with a little distilled water and then a little **FA 4**.
- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Add a few drops of bromophenol blue indicator.
- 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 sure your recorded results show the accuracy of your practical work.
- Record in a suitable form in the space below all of your burette readings and the volume of **FA 3** added in each accurate titration.

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 obtained this value.

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

(c) Calculations

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

(ii) Calculate the number of moles of sulfuric acid present in the volume of **FA 3** you calculated in **(b)**.

moles of H_2SO_4 = ... mol [1]

(iii) Use your answer to **(c)(ii)** and the information on page 4 to calculate the concentration, in mol dm^{-3}, of **Z**OH present in **FA 4**.

concentration of **FA 4** = ... mol dm^{-3} [1]

(iv) Calculate the concentration, in mol dm^{-3}, of **Z**OH in **FA 2**.

concentration of **FA 2** = ... mol dm^{-3} [1]

(v) Use your answer to **(c)(iv)** and the information on page 4 to calculate the relative atomic mass, A_r, of **Z**. Hence identify **Z**.
Show your working.

Z is ..... . [2]

(d) Using the value for the relative atomic mass of **Z** that you calculated in **(c)(v)**, calculate the percentage difference of your value from that shown in the Periodic Table.

(If you did not obtain a value for the A_r of **Z**, assume it is 32.0. Note, this is **not** the correct value.)

percentage difference = ... % [1]

[Total: 15]

[Turn over

Qualitative analysis

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

At each stage of any test you are to record details of the following:

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

You should indicate clearly at what stage in a test a change occurs.

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

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

No additional tests for ions present should be attempted.

3 Half-fill the 250 cm^3 beaker with water and place it on a tripod and gauze above a heatproof mat. Heat the water until boiling and then turn off the Bunsen burner. You will use this as a hot water-bath in **3(b)(i)**.

(a) **FA 5**, **FA 6** and **FA 7** are solutions. Each solution contains one cation and one anion. Carbonate, CO_3^{2-}, is **not** present in any of the solutions.

(i) Carry out the following tests and record your observations.
Use a 1 cm depth of solution in a test-tube for each test.

test	*observations*		
	FA 5	**FA 6**	**FA 7**
Test 1 Add an equal depth of dilute sulfuric acid.			
Test 2 Add an equal depth of aqueous sodium carbonate.			
Test 3 Add an equal depth of aqueous magnesium chloride.			

[5]

(ii) Use your observations in **(a)(i)** to suggest a **possible** formula for each of the following:

The cation in **FA 5** is ..... .

The cation in **FA 6** is ..... .

The anion in **FA 7** is ..... .

[3]

(iii) Apart from using an indicator, suggest a further test that would confirm the identity of the anion in **FA 7**.

Carry out this test and record the result.

.....

.....

..... [1]

(iv) Did the result of your test in **(a)(iii)** confirm the identity of the anion in **FA 7**?
Explain your answer.

.....

.....

..... [1]

[Turn over

(b) **FA 8** is an aqueous solution.

(i) Carry out the following tests and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 8** in a test-tube, add a few drops of acidified potassium manganate(VII). Place the tube in the hot water-bath.	
Test 2 To a 1 cm depth of **FA 8** in a test-tube, add a 1 cm length of magnesium ribbon.	

[2]

(ii) For each observation, state what you can conclude about the chemical properties of **FA 8**.

Test 1 .....

Test 2 .....

[2]

[Total: 14]

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Qualitative Analysis Notes

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	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

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
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

1	2											13	14	15	16	17	18
						Group											
							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	3	4	5	6	7	8	9	10	11	12	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 –