Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

5609029097

CHEMISTRY **9701/33**

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.

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 Group 1 metal carbonates have the formula $\mathbf{M}_2CO_3$. The identity of the metal ion, $\mathbf{M}^+$, may be determined by a gravimetric method. The metal carbonate is reacted with excess acid and the mass of carbon dioxide given off is measured.

$$\mathbf{M}_2CO_3(s) + 2HCl(aq) \rightarrow 2\mathbf{M}Cl(aq) + H_2O(l) + CO_2(g)$$

FA 1 is a Group 1 metal carbonate, $\mathbf{M}_2CO_3$.
FA 2 is 2.0 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of **FA 2** into a conical flask. Weigh the flask with the acid and record the mass.
- Weigh the container with **FA 1** and record the mass.
- **Carefully** tip all of **FA 1** into the acid in the conical flask. Swirl the contents of the flask and leave the flask to stand.
- Weigh the container with any residual **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** added to the conical flask.
- Calculate and record the theoretical initial mass of flask + acid + **FA 1**.
- Swirl the flask occasionally while leaving it to stand for approximately 5 minutes.

During this step you may wish to start Question 2 or Question 3.

- Weigh the flask and contents and record this mass.
- Calculate and record the mass of carbon dioxide given off during the experiment.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the number of moles of carbon dioxide given off in the experiment.

moles of CO_2 = ... mol [1]

(ii) Calculate the relative formula mass, M_r, of $\mathbf{M}_2CO_3$.

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

(iii) Identify the Group 1 cation, $\mathbf{M}^+$, in **FA 1**.
Show your working.

$\mathbf{M}^+$ is .... [1]

(c) One source of error in this experiment is the solubility of carbon dioxide in water.

(i) Suggest **one** modification, to the method in **(a)**, to reduce the solubility of carbon dioxide in the solution in the flask.

....

.... [1]

(ii) An assumption made in the method in **(a)** is that the acid is in excess.

Show by calculation that this assumption is true.

[2]

[Total: 10]

2 The identity of a Group 1 metal carbonate may also be found by a titration method.

M$^+$ in this question may or may not be the same cation as that in **Question 1**.

$$M_2CO_3(s) + 2HCl(aq) \rightarrow 2MCl(aq) + H_2O(l) + CO_2(g)$$

FA 3 is an aqueous solution containing 7.46 g dm^{-3} of a Group 1 metal carbonate, **M**$_2$CO$_3$.
FA 4 is 0.110 mol dm^{-3} hydrochloric acid, HC*l*.
bromophenol blue indicator

(a) Method

- Fill the burette with **FA 4**.
- Pipette 25.0 cm^3 of **FA 3** 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 any recorded results show the accuracy of your practical work.
- Record, in a suitable form below, all your burette readings and the volume of **FA 4** 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 3** required .... cm^3 of **FA 4**. [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 hydrochloric acid present in the volume of **FA 4** calculated in **(b)**.

moles of HC*l* = ... mol [1]

(iii) Calculate the number of moles of Group 1 metal carbonate, $\mathbf{M}_2CO_3$, present in 25.0 cm^3 of **FA 3**.

moles of $\mathbf{M}_2CO_3$ in 25.0 cm^3 = ... mol [1]

(iv) Calculate the relative formula mass, M_r, of $\mathbf{M}_2CO_3$.

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

(v) Identify the cation, $\mathbf{M}^+$.
Show your working.

$\mathbf{M}^+$ is .... [1]

(d) A student carrying out a similar experiment, using the same method, found the cation in **Question 2** to be Rb^+. The student is told that the acid provided, **FA 4**, was incorrectly prepared. The cation in the student's experiment should have been identified as K^+.

State whether the acid supplied is more, or less, concentrated than 0.110 mol dm^{-3}.
Explain your answer.

....

....
[1]

[Total: 14]

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 **(a)** **FA 5** is a salt containing one cation and one anion, both of which are listed in the Qualitative Analysis Notes.

(i) Place a small spatula measure of **FA 5** into a hard-glass test-tube and heat the tube, gently at first and then more strongly.
Record **all** your observations.

....

....

....

.... [2]

(ii) Place the remaining **FA 5** into a 100 cm^3 beaker and add approximately 15 cm^3 of distilled water. Stir to make a solution. This solution is **FA 6**.
You will use portions of **FA 6** for the following test and tests in **(b)**.

To a 1 cm depth of **FA 6** in a test-tube add a 1 cm depth of dilute hydrochloric acid.
Record your observations.

....

.... [1]

(b) (i) **FA 7** and **FA 8** are solutions each containing one cation and one anion, all of which are listed in the Qualitative Analysis Notes.

Carry out the following tests in separate test-tubes. Use a 1 cm depth of each solution unless otherwise specified.

	observations		
solution	**FA 6**	**FA 7**	**FA 8**
Add a few drops of aqueous silver nitrate.			
FA 6			
FA 7			

[4]

(ii) Carry out tests using aqueous sodium hydroxide and dilute sulfuric acid to identify or confirm the identity of the ions in **FA 6**, **FA 7** and **FA 8**.
Record your tests and observations in a table in the space below.

[5]

(c) **(i)** From your observations in **(a)** and **(b)** identify the cation and the anion present in each of **FA 6**, **FA 7** and **FA 8** by giving their formulae.

	cation	*anion*
FA 6		
FA 7		
FA 8		

[3]

(ii) Give an ionic equation for a precipitation reaction observed in **(b)(i)**. Include state symbols.

.... [1]

[Total: 16]

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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

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 A*l* aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 C*l* 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 T*l* 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 F*l* 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 –