

# Cambridge International AS & A Level

CANDIDATE NAME					
CENTRE NUMBER			CANDIDATE NUMBER		

CHEMISTRY 9701/33

Paper 3 Advanced Practical Skills 1

February/March 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.

#### **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.

Session
Laboratory

For Examiner's Use		
1		
2		
3		
Total		

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

2

### **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 In this experiment you will carry out a titration to identify the Group 1 metal, **M**, present in a metal hydrogencarbonate, **M**HCO<sub>3</sub>.

**FA 1** is 0.0550 mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>. **FA 2** is the metal hydrogencarbonate, **M**HCO<sub>3</sub>. bromophenol blue indicator

### (a) Method

### Preparing a solution of FA 2

- Weigh the stoppered container of **FA 2**. Record the mass in the space below.
- Tip all the FA 2 into the beaker.
- Reweigh the container with its stopper. Record the mass.
- Calculate and record the mass of FA 2 used.
- Add approximately 100 cm<sup>3</sup> of distilled water to FA 2 in the beaker.
- Stir the mixture with a glass rod until all the FA 2 has dissolved.
- Transfer this solution into the 250 cm<sup>3</sup> volumetric flask.
- Wash the beaker with distilled water and transfer the washings to the volumetric flask.
- Rinse the glass rod with distilled water and transfer the washings to the volumetric flask.
- Make up the solution in the volumetric flask to the mark using distilled water.
- Shake the flask thoroughly.
- This solution of MHCO<sub>3</sub> is FA 3. Label the flask FA 3.

#### **Titration**

- Fill the burette with **FA 1**.
- Pipette 25.0 cm³ of **FA 3** into a conical flask.
- Add a few drops of bromophenol blue indicator to the conical flask.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is ...... cm<sup>3</sup>.

		•			
	<ul> <li>Carry out as many accurate titrations as you think necessary to obtain consistent results.</li> <li>Make sure any recorded results show the precision of your practical work.</li> <li>Record in a suitable form below all of your burette readings and the volume of FA 1 added in each accurate titration.</li> </ul>				
			I		
			II		
			III		
			IV		
			V	Ī	
			VI	Ī	
			VII	Ī	
			VIII	Ī	
			[8]	-	
/I= \	<b>-</b>	om your accurate titration results, obtain a suitable value for the volume of <b>FA 1</b> to be u			
	-	ow clearly how you obtained this value.  25.0 cm <sup>3</sup> of <b>FA 3</b> required	[1]		
(c)	Cal	culations			
	(i)	Give your answers to (c)(ii), (c)(iii), (c)(iv) and (c)(v) to the appropriate number significant figures.	r of [1]		
	(ii)	Calculate the number of moles of sulfuric acid present in the volume of <b>FA 1</b> calculate <b>(b)</b> .	d in		
		moles of H <sub>2</sub> SO <sub>4</sub> = mol	[1]		
(	(iii)	Complete the equation for the reaction of sulfuric acid and $\mathbf{M}HCO_3$ . State symbols are not required.			
		$$ MHCO $_3$ + $$ H $_2$ SO $_4$ $\rightarrow$ $$ M $_2$ SO $_4$ + $$			

moles of  $\mathbf{M}HCO_3 = \dots mol$  [1]

Use your answer to (c)(ii) to deduce the number of moles of  $\mathbf{M}\mathsf{HCO}_3$  used in each titration.

(IV)	Use your answer to (c)(III) and your data on page 2 to calculate the relative formula mass, $M_r$ , of MHCO <sub>3</sub> .
	$M_{\rm r}$ of MHCO <sub>3</sub> =[1]
(v)	Calculate the relative atomic mass, $A_{r}$ , of $\mathbf{M}$ .
	$A_{r}$ of $\mathbf{M} = \dots$
	Suggest the identity of <b>M</b> .
	<b>M</b> is[1]
(d) (i)	A student used a pipette that was labelled 25.0 ± 0.06 cm³ to measure <b>FA 3</b> .
	Show how you calculate the maximum percentage error in the volume of <b>FA 3</b> .
	[1]
(ii)	The student suggested that it would have been more accurate to measure the volume of <b>FA 3</b> with a burette instead of the pipette.
	State and explain whether you agree with the student.
	[1]
	[Total: 16]

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In this experiment you will determine the relative formula mass of the same metal hydrogencarbonate, MHCO<sub>3</sub>, by thermal decomposition. Then you will compare the result obtained with your answer from 1(c)(iv).

FA 4 is another sample of the metal hydrogencarbonate, MHCO<sub>3</sub>.

#### (a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the FA 4 from the container into the crucible.
- Weigh the crucible, lid and FA 4. Record the mass.
- Calculate and record the mass of FA 4 used.
- Place the crucible and contents on a pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately one minute.
- Heat strongly, with the lid off, for a further four minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.

### During each cooling period, you may wish to work on Question 3.

- When the crucible has cooled, weigh the crucible with its lid and contents. Record the mass.
- Heat strongly, with the lid off, for a further two minutes.
- Replace the lid and leave the crucible to cool for at least five minutes.
- When the crucible has cooled, reweigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of residue obtained.
- This residue is FA 5.

## Keep FA 5 for use in 2(b)(i).

#### Results

[5]

**(b) (i)** Pour a 1 cm depth of dilute hydrochloric acid into a test-tube. Add a spatula measure of residue **FA 5** to the acid.

Record <b>all</b> your observations and identify any gas formed.	
	[2

(ii)	Use your observations in <b>(b)(i)</b> to identify the anion in <b>FA 5</b> . Assume all the $\mathbf{M}HCO_3$ has decomposed.
	Anion in <b>FA 5</b> is
(iii)	Steam is produced when the metal hydrogencarbonate, <b>FA 4</b> , is thermally decomposed.
	Use your answer in <b>(b)(ii)</b> to complete the equation for the thermal decomposition of $\mathbf{M}HCO_3$ . Include state symbols.
	<b>M</b> HCO <sub>3</sub> (s) $\rightarrow$ CO <sub>2</sub> (g) + + [1]
(iv)	The number of moles of carbon dioxide given off during the thermal decomposition is given by the formula below.
	moles of $CO_2 = \frac{\text{mass lost during heating}}{(M_r \text{ of } CO_2 + M_r \text{ of } H_2O)}$
	Calculate the number of moles of carbon dioxide given off.
	moles CO <sub>2</sub> = mol [1]
(v)	Calculate the relative formula mass, $M_r$ , of <b>M</b> HCO <sub>3</sub> .
	Show how you obtained your answer using your data from Question 2.
	$M \circ f M \sqcup CO = $
(!\	$M_{\rm r}$ of MHCO <sub>3</sub> =
(vi)	You have obtained two values for the $M_r$ of MHCO <sub>3</sub> ; one in 1(c)(iv) and another in 2(b)(v).
	State which value is likely to be more accurate. Explain your answer in terms of the practical procedures used.
	The $M_r$ obtained in Question is more accurate.
	reason
	[1]
	[Total: 12]

### **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

notes.

3

- 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.

(ii) Identify the ion that **must** be present in **FA** 6.

(i)	Heat <b>FA 6</b> gently for one minute in the hard-glass test-tube in which it is supplied. Then heat strongly until no further change occurs.
	Record <b>all</b> of your observations.
	[2

(a) FA 6 contains one cation and one anion both of which are listed in the Qualitative analysis

[Total: 12]

# (b) (i) FA 7 and FA 8 are aqueous solutions.

Each solution contains one cation and one anion both of which are listed in the Qualitative analysis notes.

Use 1 cm depths of **FA 7** or **FA 8** in test-tubes for the following tests.

Complete the table by recording your observations.

	observations				
test	FA 7	FA 8			
Test 1 Add a few drops of aqueous acidified potassium manganate(VII), then add a few drops of starch indicator.					
Test 2 Add a few drops of aqueous silver nitrate, then					
add aqueous ammonia.					
Test 3 Add aqueous sodium hydroxide, then					
pour the mixture into a boiling tube. Warm gently and <b>carefully</b> , then					
add a piece of aluminium foil.					
Test 4 Add a few drops of dilute sulfuric acid.					
		[6]			
(ii) Deduce the chemica	Il formulae of <b>FA 7</b> and <b>FA 8</b> .				
<b>FA 7</b> is	and <b>FA 8</b> is	[2]			
(iii) Give the ionic equati Include state symbol	on for the reaction of <b>FA 8</b> with sulfuls.	ıric acid.			
		[1]			

# **Qualitative analysis notes**

# 1 Reactions of aqueous cations

inn	reaction with				
ion	NaOH(aq)	NH <sub>3</sub> (aq)			
aluminium, Al³+(aq)	white ppt. soluble in excess	white ppt. insoluble in excess			
ammonium, NH <sub>4</sub> +(aq)	no ppt. ammonia produced on heating	_			
barium, Ba <sup>2+</sup> (aq)	faint white ppt. is nearly always observed unless reagents are pure	no ppt.			
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.			
chromium(III), Cr³+(aq)	grey-green ppt. soluble in excess	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), Fe³+(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), Mn²+(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, Zn²+(aq)	white ppt. soluble in excess	white ppt. soluble in excess			

# 2 Reactions of anions

ion	reaction
carbonate, CO <sub>3</sub> <sup>2-</sup>	CO <sub>2</sub> liberated by dilute acids
chloride, C <i>l</i> <sup>-</sup> (aq)	gives white ppt. with Ag <sup>+</sup> (aq) (soluble in NH <sub>3</sub> (aq))
bromide, Br <sup>-</sup> (aq)	gives cream ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq))
iodide, I <sup>-</sup> (aq)	gives yellow ppt. with Ag <sup>+</sup> (aq) (insoluble in NH <sub>3</sub> (aq))
nitrate, NO <sub>3</sub> -(aq)	NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and A <i>l</i> foil
nitrite, NO <sub>2</sub> -(aq)	NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and A <i>l</i> foil
sulfate, SO <sub>4</sub> <sup>2-</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids)
sulfite, SO <sub>3</sub> <sup>2-</sup> (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in excess dilute strong acids)

# 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 (ppt. dissolves with excess CO <sub>2</sub> )
chlorine, Cl <sub>2</sub>	bleaches damp litmus paper
hydrogen, H <sub>2</sub>	'pops' with a lighted splint
oxygen, O <sub>2</sub>	relights a glowing splint

The Periodic Table of Elements

			<i>a</i>	ε		<b>a</b>		2			E &			3.31		~	c 6		_	c				7
	18	2	Ĭ	heliu	10	ž	neor	20.3	18	Ā	argon 39.9	36	조	kryptc 83.8	54	×	xeno 131.	86	쪼	rado				
	17				σ	ш	fluorine	19.0	17	Cl	chlorine 35.5	32	Ā	bromine 79.9	53	Ι	iodine 126.9	82	Αt	astatine -				
	16				00	0	oxygen	16.0	16	ഗ	sulfur 32.1	34	Se	selenium 79.0	52	<u>a</u>	tellurium 127.6	84	Ъ	polonium –	116	^	livermorium	
	15				7	Z	nitrogen	14.0	15	₾	phosphorus 31.0	33	As	arsenic 74.9	51	Sp	antimony 121.8	83	<u>.</u>	bismuth 209.0				
	41				9	· O	carbon	12.0	14	S	silicon 28.1	32	Ge	germanium 72.6	20	S	tin 118.7	82	Ъ	lead 207.2	114	Fl	flerovium	
	13				22	- Δ	poron	10.8	13	Αl	aluminium 27.0	31	Ga	gallium 69.7	49	In	indium 114.8	81	lΤ	thallium 204.4				
											12	30	Zu	zinc 65.4	48	g	cadmium 112.4	80	БĤ	mercury 200.6	112	ပ်	copernicium	
											1	29	ŋ	copper 63.5	47	Ag	silver 107.9	62	Αu	gold 197.0	111	Rg	roentgenium -	
dr											10	28	ï	nickel 58.7	46	Pd	palladium 106.4	78	Ŧ	platinum 195.1			darmstadtium –	4
Group											0	27	ဝိ	cobalt 58.9	45	몺	rhodium 102.9	11	ŗ	iridium 192.2	109	¥	meitnerium	
		-	I	hydrogen 1.0	2						80	26	Pe	iron 55.8	44	Ru	ruthenium 101.1	92	SO	osmium 190.2	108	ΗS	hassium	
											7	22	M	manganese 54.9	43	ည	technetium -	75	Re	rhenium 186.2	107	В	bohrium	
						О		S			9	24	ပ်	chromium 52.0	42	Mo	molybdenum 95.9	74	>	tungsten 183.8	106	Sg	seaborgium	
				Kev	atomic number	atomic symbo	name	relative atomic mass			2	23	>	vanadium 50.9	41	q	niobium 92.9	73	<u>Б</u>	tantalum 180.9	105	Op	dubnium	
					Te de	aton		relati			4	22	j	titanium 47.9	40	Zr	zirconium 91.2	72	茔	hafnium 178.5	104	잪	rutherfordium -	
									I		က	21	Sc	scandium 45.0	39	>	yttrium 88.9	57-71	lanthanoids		89–103	actinoids		
	2				4	Be	beryllium	0.6	12	Mg	magnesium 24.3	20	Ca	calcium 40.1	38	ഗ്	strontium 87.6	56	Ba	barium 137.3	88	Ra	radium	1
	_				e	· :=	lithium	6.9	11	Na	sodium 23.0	19	×	potassium 39.1	37	Rb	rubidium 85.5	55	Cs	caesium 132.9	87	ь Б	francium	

Lu Lu	lutetium 175.0	103	۲	lawrencium	ı
°° X	ytterbium 173.1	102	8	nobelium	ı
e9 L	thulium 168.9	101	Md	mendelevium	ı
<sub>88</sub> <u>п</u>	erbium 167.3	100	Fm	ferminm	ı
67 Ho	holmium 164.9	66	Es	einsteinium	ı
® Q	dysprosium 162.5	86	ర	californium	ı
c5 dT	terbium 158.9	26	益	berkelium	ı
<sup>2</sup> PO	gadolinium 157.3	96	CB	curium	ı
En Eu	europium 152.0	96	Am	americium	ı
ss Sm	samarium 150.4	94	Pn	plutonium	1
Pm	promethium —	93	ď	neptunium	ı
<sup>09</sup> PN	neodymium 144.4	92	$\supset$	uranium	238.0
59 P	praseodymium 140.9	91	Ра	protactinium	231.0
Se Se	cerium 140.1	06	ᄕ	thorium	232.0
57 La	lanthanum 138.9	68	Ac	actinium	1

lanthanoids

actinoids

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