Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

0123456789

CHEMISTRY **9701/03**

Paper 3 Advanced Practical Skills **For examination from 2020**

SPECIMEN PAPER **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 [ ].

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

This document has **12** pages. Blank pages are indicated.

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1 Sodium hydrogencarbonate, $NaHCO_3$, is used as baking soda in cooking. Baking soda may also contain small amounts of other chemicals.

In this experiment, you will determine the percentage purity by mass of an impure sample of $NaHCO_3$ by titration with sulfuric acid.

FA 1 is 0.0500 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 2 is impure $NaHCO_3$
methyl orange

(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^3 of distilled water to the **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^3 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 impure $NaHCO_3$ is **FA 3**. Label the flask **FA 3**.

Results

Titration

- Fill the burette with **FA 1**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add several drops of methyl orange.
- 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 below all of your burette readings and the volume of FA 1 added in each accurate titration.

Keep FA 1 for use in Question 2.

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 1** to be used in your calculations.
Show clearly how you obtained this value.

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

(c) Calculations

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

(i) Calculate the number of moles of sulfuric acid present in the volume of **FA 1** calculated in **(b)**.

moles of H_2SO_4 = ... mol

(ii) Balance the equation for the reaction of sulfuric acid and sodium hydrogencarbonate. State symbols are not required.

.......$NaHCO_3$ + ...H_2SO_4 → ....Na_2SO_4 + ...CO_2 + ...H_2O

(iii) Using your answers to **(i)** and **(ii)**, calculate the number of moles of sodium hydrogencarbonate used in each titration.

moles of $NaHCO_3$ = ... mol

(iv) Using your answer to **(iii)**, calculate the mass of sodium hydrogencarbonate present in the mass of FA 2 used to prepare FA 3.

mass of $NaHCO_3$ = ... g

(v) Calculate the percentage purity by mass of the impure sodium hydrogencarbonate sample, **FA 2**.

percentage purity by mass of impure $NaHCO_3$, **FA 2** = ...%

(vi) What did you assume about the impurities in **FA 2** when you calculated the percentage purity?

....

....

(vii) A volumetric flask was labelled 250.0 ± 0.10 cm^3.

Calculate the maximum percentage error when using this volumetric flask.

maximum percentage error = ...%
[7]

[Total: 16]

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2 When baking soda is heated, carbon dioxide is produced. In this experiment you will investigate the reaction taking place when the sodium hydrogencarbonate in baking soda is thermally decomposed.

FA 4 is baking soda (impure $NaHCO_3$). Its composition is the same as that of **FA 2**.

(a) Method

Record all your readings in the space below.

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

While the crucible is cooling you may wish to begin work on Question 3.

- When it is cool, weigh the crucible with its lid and contents.
- 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 it is cool, weigh the crucible with its lid and contents.
- Calculate and record the mass of residue obtained.
- This residue is **FA 5**. Keep this for use in **2(d)**.

Results

I	
II	
III	
IV	

[4]

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[Turn over

(b) Calculations

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

(i) Use the percentage purity by mass of **FA 2** you calculated in **1(c)(v)**, to calculate the mass of sodium hydrogencarbonate in the sample of **FA 4** that you weighed out.

(If you were unable to carry out the calculation in **1(c)(v)**, assume that the percentage purity by mass of **FA 2** is 95.8%.)

mass of $NaHCO_3$ in **FA 4** weighed out = ... g

(ii) Calculate the mass of impurity present in your sample of **FA 4**.

mass of impurity = ... g

(iii) The impurity in **FA 4** does not decompose when it is heated.
This means that the residue, **FA 5**, contains the mass of impurity calculated in **(ii)** together with the solid decomposition product of sodium hydrogencarbonate.

Calculate the mass of the solid decomposition product.

mass of solid decomposition product = ... g

(iv) Use your answers to **(i)** and **(iii)** to calculate the mass of solid decomposition product that would be obtained if 84.0 g of **pure** sodium hydrogencarbonate were heated.

mass of solid decomposition product = ... g

(v) A student carried out the experiment by heating to constant mass and calculated that heating 84.0 g of pure $NaHCO_3$ would produce 52.3 g of the solid decomposition product. The student then suggested the following equation for the thermal decomposition of sodium hydrogencarbonate.

$$NaHCO_3(s) \rightarrow NaOH(s) + CO_2(g)$$

Use data from the Periodic Table on page 12 to explain why the student's suggestion cannot be correct.

....

....
[4]

(c) **(i)** Why was the lid put on while the crucible and its contents cooled?

....

....

(ii) The experiment could be made more accurate by heating to constant mass or using a more accurate balance. Suggest a further improvement to make the experiment more accurate.

....

....

[2]

(d) **(i)** Pour a 1 cm depth of sulfuric acid, **FA 1**, into a test-tube.
Add some **FA 5** from the crucible to the acid in the test-tube.
Record all your observations.

....

....

....

(ii) Use your observation(s) in **(i)** to identify an anion present in **FA 5**.
Explain your answer.

identity ....

explanation ....

....

(iii) Steam is one of **three** products obtained when sodium hydrogencarbonate is thermally decomposed.

Use your answer in **(ii)** to complete and balance the equation for the thermal decomposition of sodium hydrogencarbonate. Include state symbols.

........NaHCO3(s) $\rightarrow$ ....H2O(g) + ...CO2(g) + ...

(iv) State whether the balanced equation in **(iii)** agrees with the student's results given in **2(b)(v)**.
Show working in order to explain your answer.

....

....

[4]

[Total: 14]

3 Qualitative Analysis

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

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

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

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.
Rinse and reuse test-tubes and boiling tubes where possible.

(a) (i) **FA 6** and **FA 7** are aqueous solutions.
Each solution contains one cation and one anion from those listed in the Qualitative Analysis Notes.

Use 1 cm depths of **FA 6** or **FA 7** in test-tubes for the following tests.
Complete the table by recording your observations.

test	*observations*	
	FA 6	**FA 7**
Add a few drops of aqueous barium chloride or aqueous barium nitrate, then		
add dilute nitric acid.		
Add a few drops of aqueous silver nitrate.		
Add a small spatula measure of sodium carbonate. Shake the mixture.		

(ii) From your observations, deduce which solution, **FA 6** or **FA 7**, has the lower pH.
Give your evidence.

solution with lower pH ....

evidence ....

....
[4]

(b) Choose **two** reagents that would allow you to identify the cations in **FA 6** and **FA 7**.

reagents .... and ....

Use these reagents to test solutions **FA 6** and **FA 7**.
Record all your observations in the space below.

[4]

(c) Deduce the chemical formulae of FA 6 and FA 7.

FA 6 ....

FA 7 ....

[2]

[Total: 10]

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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 [Ca2+(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	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; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
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

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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 –		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 –

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