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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

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CHEMISTRY **9701/36**

Paper 3 Advanced Practical Skills 2 **October/November 2024**

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 **12** pages.

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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 accuracy 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 Sodium carbonate reacts with hydrochloric acid to release carbon dioxide as shown.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

You will find the percentage purity in a sample of impure sodium carbonate by reacting it with excess hydrochloric acid and measuring the volume of carbon dioxide formed. You may assume that the impurity does not react with acid to produce a gas.

FB 1 is impure sodium carbonate, Na_2CO_3.
FB 2 is hydrochloric acid, HCl.

(a) Method

- Weigh the container with **FB 1**. Record the mass.
- 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.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FB 2** into the flask labelled **X**. Check the bung fits tightly into the neck of flask **X**, clamp flask **X** and place the delivery tube into the inverted 250 cm^3 measuring cylinder.
- Remove the bung from the neck of the flask. Tip all the **FB 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 has stopped.
- Remove the flask from the clamp occasionally, swirl it and replace the flask in the clamp.
- Weigh the empty container that held **FB 1**. Record the mass.
- Calculate and record the mass of **FB 1** added.
- When no more gas is collected, record the final volume of gas produced.

You may wish to start Question 2 while the gas is being produced.

Results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Give your answers to each part of **(b)(ii)**, **(b)(iii)** and **(b)(iv)** to an appropriate number of significant figures.

[1]

(ii) Calculate the amount, in mol, of carbon dioxide collected in the 250 cm^3 measuring cylinder.

amount of CO_2 = ... mol [1]

(iii) Use your answer to **(b)(ii)** to deduce the amount, in mol, of the sodium carbonate present in the **FB 1** you used in your experiment.

amount of Na_2CO_3 = ... mol

Use your answer to calculate the mass, in g, of sodium carbonate in your sample of **FB 1**.

mass of Na_2CO_3 = ... g
[1]

(iv) Calculate the percentage purity of **FB 1**.

percentage purity = ... % [1]

(c) Even though the bung was replaced quickly, some carbon dioxide was lost. Suggest a change you could make to minimise gas loss at this stage.

....

....

.... [1]

(d) Some carbon dioxide is not collected because it is slightly soluble in water. State a change you could make to reduce the solubility of the gas.

Do not suggest using a liquid other than water in your tub or changing the volume of water used.

....

....

.... [1]

(e) State the uncertainty in a single reading of your balance.

uncertainty = ± .... g

Calculate the maximum percentage error in the mass of **FB 1** used in **(a)**.

maximum percentage error = ... %
[1]

[Total: 11]

DO NOT WRITE IN THIS MARGIN

2 Many metal carbonates, such as magnesium carbonate, decompose to form the metal oxide when heated.

$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

Other metal carbonates, such as sodium carbonate, Na_2CO_3, do not decompose at the temperature produced by a Bunsen burner.

FB 3 is a mixture that contains only sodium carbonate, Na_2CO_3, and magnesium carbonate.

You will carry out an experiment involving thermal decomposition to find the percentage of each of these metal carbonates in this mixture.

(a) Method

- Weigh the empty crucible with its lid. Record the mass.
- Transfer all the **FB 3** from the container into the crucible.
- Weigh the crucible, lid and **FB 3**. Record the mass.
- Calculate and record the mass of **FB 3** used.
- Place the crucible and contents on the pipe-clay triangle.
- Heat the crucible gently, with the lid on, for approximately 1 minute.
- Heat strongly, with the lid off, for a further 5 minutes.
- Leave the crucible with its contents until it is cool.

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

- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Heat the crucible strongly, with the lid off, for approximately 4 minutes.
- Allow the crucible and contents to cool.
- When the crucible is cool, weigh the crucible with its lid and contents. Record the mass.
- Calculate and record the mass of residue.
- Calculate and record the mass of carbon dioxide produced.

Leave the crucible and contents to become completely cool for use in Question 2(c).

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

(i) Calculate the amount, in mol, of carbon dioxide produced in the decomposition.

amount of CO_2 = ... mol [1]

(ii) Calculate the mass of magnesium carbonate in **FB 3**.

mass of $MgCO_3$ = ... g [1]

(iii) Calculate the percentages by mass of magnesium carbonate and sodium carbonate in **FB 3**.

percentage by mass of $MgCO_3$ = ... %

percentage by mass of Na_2CO_3 = ... %
[1]

(c) (i) Add a few drops of water to the cool residue in the crucible.
Use universal indicator to test the pH of the solution formed.
Tick (✓) one box to show the direction of the temperature change.

pH = ...

temperature goes up ☐ temperature goes down ☐ [1]

(ii) Use these observations and the information about the thermal decomposition of magnesium carbonate to write an equation for the reaction in **(c)(i)**. Include state symbols and the sign of ΔH.

.... [2]

(iii) Suggest how you would show that sodium carbonate had not decomposed during the reaction in **(a)**. State the reagent(s) and observations.

Do not carry out your test.

....

.... [2]

[Total: 13]

DO NOT WRITE IN THIS MARGIN

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 **FB 4** is a mixture of two salts that each contain one cation and one anion.
All the ions present are in the Qualitative analysis notes.

(a) Place a small spatula measure of **FB 4** into a hard-glass test-tube. Heat the tube gently at first and then more strongly.

Record all your observations and identify any gas given off.

....

....

....

....

.... [4]

(b) To a 5 cm depth of distilled water in a boiling tube, add a spatula measure of **FB 4**. Shake the tube to dissolve the **FB 4**.

(i) Carry out the following tests using a 1 cm depth of this **FB 4** solution in a test-tube for each test. Record your observations in Table 3.1.

Table 3.1

test	*observations*
Test 1 Add aqueous sodium hydroxide, then	
transfer the mixture into a boiling tube, add a piece of aluminium foil and heat gently.	
Test 2 Add an equal volume of dilute nitric acid, then	
add a few drops of aqueous silver nitrate.	
Test 3 Add aqueous barium chloride or barium nitrate, then	
add dilute nitric acid.	
Test 4 Add aqueous sodium carbonate dropwise with shaking until in excess.	

[5]

(ii) Use your observations in Table 3.1 to identify two anions which **must** be present in **FB 4**.

.... [2]

(iii) Carry out further tests to confirm or identify which two cations are present in **FB 4**. Record the reagents and conditions needed, your observations and your conclusions in a suitable table.

[5]

[Total: 16]

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^+

DO NOT WRITE IN THIS MARGIN

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	$L = 6.022 \times 10^{23}\,mol^{-1}$
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	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

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 –