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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	
CENTRE NUMBER	
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CHEMISTRY **9701/34**

Paper 3 Advanced Practical Skills 2 **May/June 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 precision of the apparatus you used in the data you record.

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

1 In this experiment you will determine the relative formula mass, M_r, of a basic metal carbonate, $\mathbf{M}CO_3{\bullet}\mathbf{M}(OH)_2$, by a titration method.

FB 1 is the basic metal carbonate $\mathbf{M}CO_3{\bullet}\mathbf{M}(OH)_2$.

FB 2 is a solution containing hydrochloric acid, HCl, and $\mathbf{M}Cl_2$, prepared using **FB 1** as follows.

- 22.50 g of **FB 1**, $\mathbf{M}CO_3{\bullet}\mathbf{M}(OH)_2$, is weighed out.
- 100.0 cm^3 of 5.00 mol dm^{-3} hydrochloric acid (a small excess) is added to **FB 1**.
- The mixture is left to allow **FB 1** to react completely.

$$\mathbf{M}CO_3{\bullet}\mathbf{M}(OH)_2(s) + 4HCl(aq) \rightarrow 2\mathbf{M}Cl_2(aq) + CO_2(g) + 3H_2O(l)$$

- The resulting solution is made up to 1.00 dm^3 with distilled water.
- This solution is **FB 2**.

FB 3 is potassium hydroxide, KOH, of concentration 5.05 g dm^{-3}.
FB 4 is thymolphthalein indicator.

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Add a few drops of **FB 4** to the conical flask.
- 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 in the space below, all your burette readings and the volume of **FB 2** 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 obtain the mean value.

25.0 cm^3 of **FB 3** required .... cm^3 of **FB 2**. [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 amount, in mol, of potassium hydroxide present in 25.0 cm^3 of **FB 3**.

amount of KOH = ... mol [1]

(iii) Give the ionic equation for the reaction of hydrochloric acid with potassium hydroxide during the titration. Include state symbols.

....

Hence calculate the concentration, in $mol\,dm^{-3}$, of hydrochloric acid in **FB 2**.

concentration of HCl = ... $mol\,dm^{-3}$ [2]

(iv) Use the information about **FB 2** and your answer to **(c)(iii)** to calculate the relative formula mass, M_r, of $\mathbf{M}CO_3 \cdot \mathbf{M}(OH)_2$.

M_r of $\mathbf{M}CO_3 \cdot \mathbf{M}(OH)_2$ = ... [2]

(d) A student suggested that the procedure used in **(a)** would be more accurate if the mass of **FB 1** used to prepare solution **FB 2** is doubled. No other change to the procedure is made.

Explain why the student is **not** correct.

....

....

.... [1]

[Total: 15]

2 In this experiment you will determine the relative atomic mass, A_r, of metal **M** by thermal decomposition of the same basic metal carbonate, $\mathbf{M}CO_3 \cdot \mathbf{M}(OH)_2$, **FB 1**.

(a) Method

- Weigh the empty crucible with its lid. Record the mass in the results section.
- Transfer all of the **FB 1** from the container into the crucible.
- Weigh the crucible, lid and **FB 1**. Record the mass.
- Calculate the mass of **FB 1** used. Record this mass in the space for other results.
- Place the crucible and contents on a 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.
- Replace the lid and leave the crucible to cool for at least 5 minutes.

During the cooling period, 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.
- Place the crucible and contents on the pipe-clay triangle. Remove the lid.
- Heat strongly for a further 2 minutes.
- Replace the lid and leave the crucible to cool for at least 5 minutes.
- When the crucible is cool, reweigh the crucible with its lid and contents. Record the mass.
- Calculate the mass of residue obtained. Record this mass in the space for other results.

Results

mass of empty crucible and lid = ...

mass of crucible, lid and **FB 1** (before heating) = ...

mass of crucible, lid and **FB 1** (after first heating) = ...

mass of crucible, lid and **FB 1** (after second heating) = ...

Other results

I	
II	
III	
IV	

[4]

(b) Calculations

(i) When **FB 1** undergoes thermal decomposition, the products are the metal oxide, **M**O, carbon dioxide and water vapour.
Give the equation for the thermal decomposition of **FB 1**. Include state symbols.

.... [1]

(ii) The amount, in mol, of carbon dioxide produced is given by the following formula.

$$\text{amount of } CO_2 = \frac{\text{mass loss during heating}}{(M_r \text{ of } CO_2 + M_r \text{ of } H_2O)}$$

Calculate the amount, in mol, of carbon dioxide produced in **(a)**.

amount of CO_2 = ... mol [1]

(iii) Calculate the relative formula mass, M_r, of the basic metal carbonate.

M_r of $\mathbf{M}CO_3\text{•}\mathbf{M}(OH)_2$ = ... [1]

(iv) Use your answer to **(b)(iii)** to calculate the relative atomic mass, A_r, of metal **M**.
Show your working.

A_r of **M** = ... [1]

(c) **(i)** Explain why the headings for the third and fourth readings in the results section in **(a)** are **not** suitable.

....

.... [1]

(ii) State whether or not your experiment would be more accurate if the crucible and its contents were heated for a third time. Explain your answer by referring to your results in **(a)**.

....

....

.... [1]

(iii) A student carries out the experiments in **Questions 1** and **2**. The student expects the value of the M_r of $\mathbf{M}CO_3\text{•}\mathbf{M}(OH)_2$ obtained by thermal decomposition in **Question 2** to be more accurate than the value of the M_r obtained by titration in **Question 1**.

State **one** reason why the student expects the experiment in **Question 2** to be more accurate.

....

.... [1]

[Total: 11]

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 (a) **FB 5** is a compound containing one cation and one anion, both of which are listed in the Qualitative analysis notes.

(i) Heat a **small** spatula measure of **FB 5** in a hard-glass test-tube until no further change occurs.
Record your observations.

....

....

....

.... [2]

(ii) Describe another test to positively identify the cation in **FB 5**.
Carry out your test and record your observations.

test ....

observations ....
[1]

(iii) Put a 1 cm depth of dilute hydrochloric acid in a test-tube. Add a **small** spatula measure of **FB 5**.
Record your observations.

....

....

....

.... [2]

(iv) Deduce the formula of **FB 5**.

FB 5 is .... [1]

Question 3 continues on page 8.

(b) You will devise chemical tests to distinguish between the two possible identities given for each of compounds **FB 6**, **FB 7**, **FB 8** and **FB 9**.

In each case you should:

- use a 1 cm depth of the solution of the unknown compound in a test-tube
- use a boiling tube if you need to warm a mixture
- use a spatula measure of the unknown solid
- record details of your test(s) and your observations
- state your conclusion about the identity of the compound.

(i) **FB 6** is either aqueous chromium(III) sulfate or aqueous iron(II) sulfate.

FB 6 is .... [2]

(ii) **FB 7** is either dilute hydrobromic acid or dilute nitric acid.
If you select a test that gives a negative result, then you must carry out a further test that gives a **positive** result.

FB 7 is .... [2]

(iii) **FB 8** is either magnesium carbonate or zinc carbonate.

FB 8 is .... [2]

(iv) **FB 9** is either aqueous methanol or aqueous ethanol.
Note: **FB 9** is flammable and should **not** be heated with a flame.
(When carrying out your test you may need to leave the reaction mixture to stand.)

FB 9 is .... [2]

[Total: 14]

DO NOT WRITE IN THIS MARGIN

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	$R = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,\text{C}\,\text{mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\,\text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,\text{C}$
molar volume of gas	$V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ}\,\text{kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J}\,\text{g}^{-1}\,\text{K}^{-1}$)

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The Periodic Table of Elements

Group																	
1	2											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			**Key** atomic number atomic symbol name relative atomic mass								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 –	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 –