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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

2010645685

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **February/March 2025**

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 Potassium alum is a hydrated salt containing aluminium ions, potassium ions and sulfate ions.

1 mol of hydrated potassium alum contains 12 mol of water of crystallisation.

Hydrated potassium alum decomposes when heated, losing its water of crystallisation and becoming anhydrous.

You will determine the formula of potassium alum by heating the hydrated salt until it becomes anhydrous.

FA 1 is hydrated potassium alum.

(a) Method

- Weigh a crucible with its lid. Record the mass in the space for results.
- Add all of the **FA 1** to the crucible.
- Weigh the crucible and lid with **FA 1**. Record the mass.
- Calculate and record the mass of **FA 1** added.
- Place the crucible on the pipe-clay triangle. Heat the crucible and contents **gently** for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 5 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

While the crucible is cooling, you may begin work on Question 2 or Question 3.

- Reweigh the crucible and contents with the lid on. Record the mass.
- Remove the lid. Heat the crucible and contents strongly for a further 2 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Reweigh the crucible and residue with the lid on. Record the mass.
- Calculate and record the mass of residue obtained.

Results

I	
II	
III	
IV	
V	

[5]

DO NOT WRITE IN THIS MARGIN

(b) Calculations

(i) Calculate the amount, in mol, of water of crystallisation lost during the thermal decomposition of **FA 1**.

amount of H_2O lost = ... mol [1]

(ii) Use the information given and your answer to **(b)(i)** to determine the amount, in mol, of potassium alum used.

amount of potassium alum = ... mol [1]

(iii) Calculate the relative formula mass, M_r, of anhydrous potassium alum.

M_r = ... [1]

(iv) Anhydrous potassium alum contains aluminium ions, potassium ions and sulfate ions.

1 mol of potassium alum also contains 1 mol of aluminium ions.

Use the M_r you have calculated in **(b)(iii)** to suggest the formula of anhydrous potassium alum.

Show your working.

The formula = ... [1]

(c) (i) The uncertainty in a single balance reading for a two decimal place balance is 0.01 g.

Calculate the maximum percentage error in your measurement of the mass of the residue of anhydrous potassium alum.

Show your working.

maximum percentage error = ...% [1]

(ii) A student obtains a higher value for the relative formula mass, M_r, of anhydrous potassium alum than expected. The student incorrectly suggests that this is because some of the anhydrous potassium alum residue decomposes to aluminium oxide and potassium oxide during strong heating.

Explain why the student's suggestion is **not** correct.

....

....

.... [1]

[Total: 11]

2 Many oxidising agents are able to oxidise acidified potassium iodide to iodine in acidic conditions. The amount of iodine produced can be determined by titrating it with aqueous sodium thiosulfate.

$$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow 2NaI(aq) + Na_2S_4O_6(aq)$$

You will determine the change in oxidation state of an oxidising agent when it reacts with iodide ions.

FA 2 is aqueous sodium thiosulfate, containing 22.00 g $Na_2S_2O_3$•$5H_2O$ (M_r = 248.2) in 1.00 dm^3.
FA 3 is a 0.0175 mol dm^{-3} solution of an oxidising agent.
FA 4 is 0.50 mol dm^{-3} potassium iodide, KI.
FA 5 is 1.00 mol dm^{-3} sulfuric acid, H_2SO_4.
FA 6 is starch solution.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Use the 10.0 cm^3 measuring cylinder to add 10 cm^3 of **FA 4**, an excess, to the conical flask.
- Use the 25.0 cm^3 measuring cylinder to add 20 cm^3 of **FA 5**, an excess, to the conical flask.
- Add **FA 2** from the burette until the solution becomes yellow.
- Add about 10 drops of **FA 6** 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 **FA 2** added in each accurate titration.

Keep FA 3, FA 4, FA 5 and FA 6 for use in Question 3.

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 **FA 3** required .... cm^3 of **FA 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 sodium thiosulfate in the volume of **FA 2** in **(b)**.

amount of $Na_2S_2O_3$ = ... mol [1]

(iii) Calculate the amount, in mol, of iodine that reacts with the amount of sodium thiosulfate in **(c)(ii)**.

amount of I_2 = ... mol [1]

(iv) Calculate the amount, in mol, of **FA 3** used to produce the amount of iodine in **(c)(iii)**.

amount of **FA 3** = ... mol [1]

(v) Calculate the amount, in mol, of iodine produced by the reaction of 1 mol of **FA 3** with potassium iodide. Give your answer to **one** decimal place.

amount of I_2 = ... mol [1]

(vi) The oxidising agent in **FA 3** is a compound of a transition metal, **M**.
The redox reaction of **FA 3** with iodide ions produces **M**$^{2+}$ ions.
Use your answer to **(c)(v)** to calculate the change in the oxidation state of **M** during this reaction.
Show your working.

The oxidation state of **M** changes from .... to .... [2]

(d) A student suggests that the experiment in **(a)** would be more accurate if the **FA 5**, sulfuric acid, is measured using a pipette.
State whether the student is correct. Explain your answer.

....

.... [1]

[Total: 16]

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) Carry out the following tests using **FA 3** and record your observations in Table 3.1.
Use a 1 cm depth of **FA 3** in a test-tube for each test.

Table 3.1

test	*observations*
Test 1 Add an equal volume of aqueous sodium hydroxide, then	
add an equal volume of aqueous sodium sulfite. Shake the mixture in the tube, then	
add sulfuric acid, **FA 5**.	
Test 2 Add an equal volume of sulfuric acid, **FA 5**, then add a small spatula measure of zinc. Allow the mixture to stand.	
Test 3 Add an equal volume of aqueous hydrogen peroxide.	

Give the formula of the gas formed in **Test 3**.

The gas formed is .... [4]

(b) **(i)** **FA 7** is a solution containing four ions, three of which are listed in the Qualitative analysis notes.
Carry out the following tests and record your observations in Table 3.2.

Use a 1 cm depth of **FA 7** for each test. A boiling tube **must** be used for Test 1 and a test-tube for the other tests.

Table 3.2

test	*observations*
Test 1 Add 0.5 cm depth of aqueous sodium hydroxide to a boiling tube, then	
warm the mixture **carefully**, then	
add aluminium foil.	
Test 2 Add several drops of aqueous potassium iodide, **FA 4**, then	
add a few drops of starch solution, **FA 6**.	
Test 3 Add the pieces of magnesium.	
Test 4 Add a few drops of aqueous barium nitrate or aqueous barium chloride, then	
add hydrochloric acid.	
Test 5 Add a few drops of aqueous silver nitrate, then	
add aqueous ammonia.	

[6]

(ii) Give the formula of each of the four ions in **FA 7**.

The ions are .... , ... , ... and .... [2]

(iii) Give the ionic equation for **one** reaction that takes place in Test 1 or Test 3 of **(b)(i)**.
Include state symbols.

.... [1]

[Total: 13]

Qualitative analysis notes

1 Reactions of aqueous 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^+

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	$L = 6.02 \times 10^{23}\,mol^{-1}$
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 –