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Cambridge Assessment International Education

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CANDIDATE NAME

CENTRE NUMBER

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CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **October/November 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	

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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 use in the data you record.

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

1 Hydrated ethanedioic acid is a diprotic acid with the formula $(COOH)_2 \bullet \mathbf{x}H_2O$ where **x** is an integer.

Ethanedioic acid reacts with manganate(VII) ions when heated.

$$5(COOH)_2(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

You will determine the value of **x** in $(COOH)_2 \bullet \mathbf{x}H_2O$ by titrating a solution containing ethanedioic acid with manganate(VII) ions.

- **FA 1** is 6.20 g dm^{-3} aqueous ethanedioic acid, $(COOH)_2 \bullet \mathbf{x}H_2O$.
- **FA 2** is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
- **FA 3** is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the measuring cylinder to add approximately 20 cm^3 of **FA 3** to the conical flask.
- Place the conical flask on a tripod and gauze and heat carefully until the temperature of the solution is approximately 70 °C.
- Remove the flame.
- Carefully lift the hot conical flask and place it on the white tile under the burette.
- Add **FA 2** drop-wise for the first 2–3 cm^3. Any initial pink colouring may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70 °C. If the brown colour disappears, continue the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- The end-point is reached when a permanent pale pink colour is formed.
- Perform a rough titration with **FA 2**. Record your burette readings in the space below.

The rough titre is ..... cm^3.

- Carry out as many titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record all your burette readings and the volume of **FA 2** added in each accurate titration.

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Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to be used in your calculations.

Show clearly how you obtained this value.

25.0 cm^3 of **FA 1** required ..... cm^3 of **FA 2**. [1]

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(c) Calculations

(i) Give your answers to **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to the appropriate number of significant figures. [1]

(ii) Calculate the amount, in mol, of manganate(VII) ions, MnO_4^-, in the volume of **FA 2** calculated in **(b)**.

amount of MnO_4^- = ... mol [1]

(iii) Calculate the amount, in mol, of ethanedioic acid that reacts with the manganate(VII) ions in **(c)(ii)**.

amount of $(COOH)_2$ = ... mol

Hence calculate the concentration, in mol dm^{-3}, of ethanedioic acid in **FA 1**.

concentration of $(COOH)_2$ = ... mol dm^{-3} [2]

(iv) Calculate the relative molecular mass, M_r, of the ethanedioic acid in **FA 1**.

M_r = ... [1]

(v) Calculate the value of **x** in $(COOH)_2 \cdot \mathbf{x}H_2O$.

Show your working.

x = ... [1]

(d) Explain why it is necessary to add **FA 3** in each titration.

.....

..... [1]

[Total: 15]

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2 Hydrated zinc sulfate has the formula $ZnSO_4 \cdot \mathbf{y}H_2O$ where **y** is an integer.

Hydrated zinc sulfate decomposes when heated, losing only its water of crystallisation and becoming anhydrous.

You will determine the value of **y** in $ZnSO_4 \cdot \mathbf{y}H_2O$ by heating the hydrated salt until it becomes anhydrous.

FA 4 is hydrated zinc sulfate, $ZnSO_4 \cdot \mathbf{y}H_2O$.

(a) Method

- Weigh the crucible with its lid. Record the mass in the space for Results.
- Add between 3.20 g and 3.40 g of **FA 4** to the crucible.
- Weigh the crucible with its lid and **FA 4**. Record the mass.
- Place the crucible on the pipeclay triangle. Gently heat the crucible and contents for approximately 2 minutes with the lid on.
- Remove the lid. Heat the crucible and contents strongly for approximately 4 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.

You may wish to begin work on Question 3 while the crucible is cooling.

- Weigh the crucible with its lid and its contents. Record the mass.
- Remove the lid. Heat the crucible strongly for approximately 3 minutes.
- Replace the lid and leave the crucible and residue to cool for at least 5 minutes.
- Weigh the crucible with its lid and its contents. Record the mass.
- Calculate the mass of **FA 4** used and the mass of residue obtained. Record the masses.

Results

I	
II	
III	
IV	
V	

[5]

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(b) Calculations

(i) Calculate the amount, in mol, of anhydrous zinc sulfate residue formed in the decomposition of **FA 4**.

amount of $ZnSO_4$ = ... mol

Calculate the amount, in mol, of water of crystallisation lost.

amount of H_2O = ... mol
[2]

(ii) Calculate the value of **y** in the formula $ZnSO_4 \cdot \mathbf{y}H_2O$.

Show your working.

y = ... [2]

(c) A student suggests using this thermal decomposition method to investigate the number of moles of water of crystallisation in hydrated ethanedioic acid. The teacher says that this method is unsuitable.

Suggest why this method is unsuitable.

.....

..... [1]

[Total: 10]

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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)** A bottle labelled **FA 5** is thought to contain hydrated zinc sulfate. It would therefore contain zinc ions and sulfate ions as well as water of crystallisation.

(i) Devise and carry out tests to investigate whether zinc ions, sulfate ions and water of crystallisation are present.

Record the tests you carry out and the observations you see in the space provided.

[5]

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(ii) Use your observations in **(a)(i)** to complete Table 3.1 to show whether each species is present in **FA 5**.

Use a tick (✓) if the species is present.

Use a cross (✗) if the species is **not** present.

Table 3.1

Zn^{2+}	
SO_4^{2-}	
H_2O	

[1]

(b) You are provided with solid **FA 6**.

(i) Heat a few crystals of **FA 6** in a hard-glass test-tube until no further gas is evolved. Record all your observations.

Leave the test-tube until it is cool.

Keep the cooled residue for use in (b)(ii).

.....

.....

..... [2]

(ii) To the cooled residue from **(b)(i)**, add approximately 3 cm depth of distilled water and stir. Filter the solution formed into a test-tube.

The colour of the solution is ..... . [1]

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(c) You are provided with aqueous solutions **FA 7** and **FA 8** and with solid **FA 9**.

FA 7 is an aqueous solution of **FA 6**.
FA 7, **FA 8** and **FA 9** contain compounds which all have one metal that is the same but which may be in different oxidation states.

(i) Carry out the following tests on **FA 7**, **FA 8** and **FA 9** and record your observations in Table 3.2. For each test use a 1 cm depth of a solution or a spatula measure of solid.

Table 3.2

test	*observations*		
	FA 7	**FA 8**	**FA 9**
Test 1 Add hydrogen peroxide.			
Test 2 Add aqueous sodium hydroxide, then			
leave to stand.			
Test 3 Add aqueous iron(II) sulfate.			

[4]

(ii) Suggest the identity of the metal in **FA 6**/**FA 7**, **FA 8** and **FA 9**.

The metal is ..... . [1]

(iii) Complete Table 3.3 to suggest the oxidation state of the metal in **FA 6**/**FA 7** and **FA 8**.

Table 3.3

	FA 6/**FA 7**	**FA 8**
oxidation state		

[1]

[Total: 15]

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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^+

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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	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

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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											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 –

Key

atomic number
atomic symbol
name
relative atomic mass

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 –

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