Cambridge Assessment
International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1

October/November 2022

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 **16** pages. Any blank pages are indicated.

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 Group 1 elements form salts with ethanedioic acid. These salts are ethanedioates and have the formula $(COO\mathbf{M})_2•2H_2O$, where **M** is the Group 1 metal.

Ethanedioate ions react with manganate(VII) ions as shown.

$$5(COO^-)_2(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

You will determine which metal is present in $(COO\mathbf{M})_2•2H_2O$ by titrating a solution of this salt with manganate(VII) ions.

FA 1 is 10.14 g dm^{-3} aqueous hydrated ethanedioate of metal **M**, $(COO\mathbf{M})_2•2H_2O$.
FA 2 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 3 is 1 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** into 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.
- During titrations, add **FA 2**, **slowly at first**, until a permanent pale pink colour is formed. The pink colour on initial addition may take several seconds to disappear.
- If the reaction mixture turns brown, reheat it to about 70 °C. If the brown colour disappears, continue with the titration. If the brown colour remains, discard the contents of the flask and begin a new titration.
- 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 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 your burette readings and the volume of **FA 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 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]

(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 ethanedioate ions that reacted with the manganate(VII) ions in **(c)(ii)**.

amount of $(COO^-)_2$ = ... mol

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

concentration of $(COO^-)_2$ = ... mol dm^{-3}
[1]

(iv) Calculate the relative formula mass, M_r, of the hydrated ethanedioate, $(COO\mathbf{M})_2\text{•}2H_2O$.

M_r = ... [1]

(v) Identify **M**. Show your working.

M is .... [2]

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

....

.... [1]

[Total: 15]

Question 2 starts on the next page.

2 Hydrated copper(II) sulfate, $CuSO_4{\bullet}5H_2O$, can lose its water of crystallisation to form anhydrous copper(II) sulfate.

The enthalpy change for the dehydration of hydrated copper(II) sulfate is shown in the equation.

$$CuSO_4{\bullet}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

You will carry out experiments to determine the enthalpy changes for the solution of hydrated and anhydrous copper(II) sulfate and then use Hess's law to determine the enthalpy change of dehydration.

FA 4 is hydrated copper(II) sulfate, $CuSO_4{\bullet}5H_2O$.
FA 5 is anhydrous copper(II) sulfate, $CuSO_4$.

(a) Determination of the enthalpy change of solution of hydrated copper(II) sulfate.

Method

- Weigh the container with **FA 4**. Record the mass.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 4** into the water and stir until the solid dissolves.
- Measure and record the lowest temperature reached.
- Rinse and dry the cup ready for the next experiment.
- Weigh the container with any residual **FA 4**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 4** used.

Results

[2]

(b) **Calculations**

(i) Calculate the energy change during this reaction.

energy change = ... J [1]

(ii) Calculate the amount, in mol, of hydrated copper(II) sulfate, **FA 4**, used in the experiment. Show your working.

amount of $CuSO_4 \bullet 5H_2O$ = ... mol [1]

(iii) Calculate the enthalpy change, in kJ mol^{-1}, when 1.00 mol of hydrated copper(II) sulfate dissolves in water. This is the enthalpy of solution.

enthalpy change of solution = ... kJ mol^{-1} [1]

sign *value*

(c) Determination of the enthalpy change of solution of anhydrous copper(II) sulfate.

Method

- Weigh the container with **FA 5**. Record the mass.
- Support the cup in the 250 cm^3 beaker.
- Use the measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Measure and record the temperature of the water.
- Tip all the **FA 5** into the water and stir until the solid dissolves.
- Measure and record the highest temperature reached.
- Weigh the container with any residual **FA 5**. Record the mass.
- Calculate and record the change in temperature.
- Calculate and record the mass of **FA 5** used.

Results

[1]

(d) Calculations

(i) Calculate the enthalpy change, in kJ mol^{-1}, for the enthalpy change of solution of anhydrous copper(II) sulfate.

enthalpy change = ... kJ mol^{-1} [2]
sign *value*

(ii) Use the enthalpy changes calculated in **(b)(iii)** and **(d)(i)** to calculate the enthalpy change of dehydration of hydrated copper(II) sulfate.

$$CuSO_4{\bullet}5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Show clearly how you obtained your answer.

enthalpy change = ... kJ mol^{-1} [1]
sign *value*

(e) In the experiments in **(a)** and **(c)** you used the same method to determine the enthalpy change of solution of two solids.

Tick the box to indicate which statement is correct.
Ignore the effect of differences in mass used.

The percentage error in **(b)(iii)** is less than the percentage error in **(d)(i)**.	
The percentage errors in **(b)(iii)** and **(d)(i)** are equal.	
The percentage error in **(b)(iii)** is greater than the percentage error in **(d)(i)**.	

Explain your choice.

....

.... [1]

[Total: 10]

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.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** **FA 6** is an aqueous solution that contains one cation and two anions. The three ions are listed in the Qualitative analysis notes.

(i) Carry out the following tests on **FA 6** and record your observations.

test	*observations*
Test 1 To a 1 cm depth of **FA 6** in a boiling tube add aqueous sodium hydroxide, then	
heat gently.	
Test 2 To a 1 cm depth of **FA 6** in a boiling tube add a 1 cm depth of aqueous sodium hydroxide and a piece of aluminium foil. Heat gently.	
Test 3 To a 1 cm depth of **FA 6** in a test-tube add a few drops of hydrogen peroxide.	

[4]

(ii) From your observations suggest **two** possible identities for the cation in **FA 6**.

possible cations: .... and .... [1]

(iii) Suggest a test that would allow you to determine which of the cations you suggested in **(a)(ii)** is present in **FA 6**.

Carry out this test, record the result and hence identify the cation in **FA 6**.

test ....

result ....

The cation present is ....

[2]

(iv) From your observations in **(a)(i)** suggest **two** anions that could be present in **FA 6** and give their formulae.

possible anions: .... or .... [1]

(v) Suggest an additional test that could be carried out to confirm the presence of **one** of the anions you suggested in **(a)(iv)**.

Carry out this test, record the result and hence state the identity of the anion.

test ....

result ....

The anion present is ....

[2]

(b) Half fill the 250 cm^3 beaker with water and heat to approximately 80 °C. Turn off the Bunsen burner. This will be your hot water bath.

FA 7 is an organic compound with an M_r between 40–57.

(i) Carry out **Test 2** and **Test 3** on **FA 7** and record your observations. The result for **Test 1** is shown in the table.

test	*observations*
Test 1 Add a small piece of sodium.	no change
Test 2 To a 0.5 cm depth of aqueous iodine in a test-tube add aqueous sodium hydroxide dropwise until the yellow colour just disappears. Then add a few drops of **FA 7** and shake the test-tube. If no change is seen, warm the test-tube in your hot water bath.	
Test 3 To a 1 cm depth of **FA 7** in a test-tube add a few drops of acidified potassium manganate(VII). Warm the test-tube in your hot water bath.	

[2]

(ii) Using the observations in **(b)(i)** suggest what can be deduced from each test about the functional groups present in **FA 7**.

Test 1 ....

Test 2 ....

Test 3 ....

[2]

(iii) Use your deductions in **(b)(ii)** to suggest the identity of **FA 7**.

FA 7 is .... [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^+

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 144.4	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 –