Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

5033027902

CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **May/June 2021**

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, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

Session
Laboratory

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.
- Notes for use in qualitative analysis are provided in the question paper.

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

1 Iron(II) sulfate crystals, $FeSO_4 \bullet xH_2O$, contain water of crystallisation. You will carry out a titration to determine the value of x in the formula, where x is an integer. A solution containing a known mass of the crystals will be titrated with acidified aqueous potassium manganate(VII) of known concentration.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

FA 1 contains 26.52 g dm^{-3} of hydrated iron(II) sulfate, $FeSO_4 \bullet xH_2O$.
FA 2 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 3 is dilute 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 25 cm^3 measuring cylinder to transfer 25 cm^3 of **FA 3** into the same conical flask.
- Carry out 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 accuracy 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.

Keep FA 1 for use in Question 3.

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable 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 an appropriate number of significant figures. [1]

(ii) Calculate the number of moles of potassium manganate(VII) present in the volume of **FA 2** calculated in **(b)**.

moles of $KMnO_4$ = ... mol [1]

(iii) Calculate the number of moles of iron(II) sulfate present in 1.00 dm^3 of **FA 1**.

moles of $FeSO_4$ = ... mol [1]

(iv) Calculate the mass of iron(II) sulfate present in 1.00 dm^3 of **FA 1**.

mass of $FeSO_4$ = ... g [1]

(v) Calculate the value of *x* in $FeSO_4{\bullet}xH_2O$.

x = ... [2]

(d) Iron(II) sulfate in solution is readily oxidised by air to form iron(III) sulfate.

State the effect, on the value of *x* calculated in **(c)(v)**, if some of your sample of **FA 1** had oxidised before you carried out the titration.
Explain your answer.

....

....

....

.... [2]

[Total: 16]

Question 2 starts on the next page.

2 In **Question 1** you used a titration method to determine the value of *x* in a hydrated salt. In **Question 2** you will use a gravimetric method. In this method a sample of solid is heated to remove the water of crystallisation.

You will carry out this method on a different hydrated compound, **FA 4**, with formula $MZ{\bullet}yH_2O$. In **FA 4** the value of *y* is an integer.

$$MZ{\bullet}yH_2O(s) \rightarrow MZ(s) + yH_2O(g)$$

FA 4 is a hydrated compound, $MZ{\bullet}yH_2O$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Place between 2.40 g and 2.60 g of **FA 4** in the crucible and record its appearance below.
- Weigh the crucible, its lid and contents and record the mass.
- Without the lid, place the crucible on the pipe-clay triangle and heat gently for approximately one minute and record your observations.
- Then heat more strongly for approximately four minutes.
- Place the lid on the crucible and leave it to cool.

You may wish to start Question 3 while you are waiting for the crucible to cool.

- Weigh the crucible, its lid and contents and record the mass.
- Calculate and record the mass of **FA 4**, the mass of residue after heating and the mass of water lost.

Keep FA 4 for use in Question 3.

Results

appearance of **FA 4** ....

observations during heating for the first minute ....

....

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the number of moles of water lost when your sample of MZ•yH_2O was heated.

moles of water = ... mol

The relative formula mass of the anhydrous compound MZ is 120.4.

Calculate the number of moles of MZ present in the residue.

moles of MZ = ... mol
[1]

(ii) Use your answers from **(b)(i)** to calculate the value of *y* in **FA 4**, MZ•yH_2O.
Show your working.

y = ... [1]

(iii) State an assumption you made when calculating the value of *y* in the hydrated compound.

.... [1]

(c) A student suggested that the experiment would be more accurate if the crucible had been heated with the lid on for the first minute.

State and explain whether you agree with the student.

....

.... [1]

[Total: 8]

Qualitative analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

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

No additional tests for ions present should be attempted.

3 **(a)** Aqueous ammonium thiocyanate reacts with aqueous iron(III) ions to form an orange or red coloured compound. Iron(II) ions do not react in this way. The darker the orange or red colour, the more iron(III) ions are present in the solution.

(i) For each test use a 1 cm depth of **FA 1** in a test-tube. Record all your observations.

test	*observations*
Test 1 Add a few drops of aqueous ammonium thiocyanate.	
Test 2 Add a few drops of aqueous sodium hydroxide and leave for at least two minutes, then	
add dilute sulfuric acid dropwise until there is no further change, then	
add a few drops of aqueous ammonium thiocyanate.	

[3]

(ii) Suggest a reason for any difference in observation when you added aqueous ammonium thiocyanate in **Test 2** compared with **Test 1**.
Your answer should refer to the type of reaction that occurred in **Test 2**.

....

....

.... [2]

(iii) The charge on the thiocyanate ion, SCN^-, is –1.

Determine the formula of ammonium thiocyanate.

.... [1]

(iv) A solution containing Fe^{2+} reacts with aqueous ammonia to form a green precipitate.

Write the ionic equation for this reaction.
Include state symbols.

.... [2]

(b) **FA 4** contains one cation and one anion, both of which are listed in the Qualitative Analysis Notes. The anion in **FA 4** contains sulfur.

(i) Carry out appropriate tests to allow you to identify the cation and anion in **FA 4**.

Record each test and your observations in a suitable form below.

[7]

(ii) Give the formula of the ions present in **FA 4**.

cation ....

anion ....

[1]

[Total: 16]

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Qualitative analysis notes

1 Reactions of aqueous cations

ion	*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 heating	–
barium, $Ba^{2+}(aq)$	faint white ppt. is nearly always observed unless reagents are pure	no ppt.
calcium, $Ca^{2+}(aq)$	white ppt. with high $[Ca^{2+}(aq)]$	no ppt.
chromium(III), $Cr^{3+}(aq)$	grey-green ppt. soluble in excess	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

ion	*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 ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$)
iodide, $I^-(aq)$	gives 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
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (soluble in excess dilute strong acids)

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 (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

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 –		114 Fl flerovium –		116 Lv livermorium –		

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 –