

Cambridge International AS & A Level

CANDIDATE NAME					
CENTRE NUMBER			CANDIDATE NUMBER		

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.

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.

Sess	ion
Labora	atory

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, $FeSO_4 \circ xH_2O$, 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.

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

FA 1 contains 26.52 g dm⁻³ of hydrated iron(II) sulfate, FeSO₄•xH₂O.

FA 2 is 0.0200 mol dm⁻³ potassium manganate(VII), KMnO₄.

FA 3 is dilute sulfuric acid, H₂SO₄.

(a) Method

- Fill the burette with **FA 2**.
- Pipette 25.0 cm³ of **FA 1** into a conical flask.
- Use the 25 cm³ measuring cylinder to transfer 25 cm³ 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
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- 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]

	m your accurate titration results, obtain a suitable value to be used in your calculations. w clearly how you obtained this value.
	25.0 cm ³ of FA 1 required cm ³ of FA 2 . [1]
(c) Cald	culations
	Give your answers to (c)(ii) , (c)(iii) and (c)(iv) to an appropriate number of significant figures.
(ii)	Calculate the number of moles of potassium manganate(VII) present in the volume of ${\bf FA~2}$ calculated in ${\bf (b)}$.
	moles of $KMnO_4 = \dots mol [1]$
(iii)	Calculate the number of moles of iron(II) sulfate present in 1.00 dm³ of FA 1 .
(iv)	moles of $FeSO_4 = \dots mol$ [1] Calculate the mass of iron(II) sulfate present in 1.00 dm ³ of FA 1 .
(11)	Calculate the mass of men(n) canate process in modern of 174 in
	mass of FeSO ₄ = g [1]
(v)	Calculate the value of x in FeSO ₄ • x H ₂ O.
	<i>x</i> = [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 $MZ \cdot yH_2O$. In **FA 4** the value of y is an integer.

$$MZ \cdot yH_2O(s) \rightarrow MZ(s) + yH_2O(g)$$

FA 4 is a hydrated compound, MZ•*y*H₂O.

(a) Method

Results

- 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.

observations during heating for the first minute	
observations during heating for the first minute	

I II III IV

[4]

(b)	Ca	lcu	lati	ons

Calculate the number of moles of water lost when your sample of MZ•yH ₂ O was heated.	(i)
moles of water = mo	
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 = mo	
Use your answers from (b)(i) to calculate the value of y in FA 4, MZ•yH₂O. Show your working.	(ii)
<i>y</i> = [1]	
) State an assumption you made when calculating the value of y in the hydrated compound	(iii)
[1]	
student suggested that the experiment would be more accurate if the crucible had been eated with the lid on for the first minute.	
tate and explain whether you agree with the student.	Sta
[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 .	ous
		[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]

[Total: 16]

(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 appropri	ate tests to allo	w you to identif	y the cation	and anion in FA 4
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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]

11

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12

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Qualitative analysis notes

1 Reactions of aqueous cations

i	reaction with									
ion	NaOH(aq)	NH ₃ (aq)								
aluminium, Al³+(aq)	white ppt. soluble in excess	white ppt. insoluble in excess								
ammonium, NH₄⁺(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), Cr³+(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), Fe²+(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), Fe³+(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess								
magnesium, Mg²+(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess								
manganese(II), Mn²+(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, C <i>l</i> ⁻ (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 A <i>l</i> foil
nitrite, NO ₂ -(aq)	NH₃ liberated on heating with OH⁻(aq) and A <i>l</i> 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

	18	۵ ت ۲	helium 4.0	10	Ne	neon 20.2	18	Ā	argon 39.9	36	궃	krypton 83.8	54	Xe	xenon 131.3	98	Ru	radon				
	17			6	ш	fluorine 19.0	17	Cl	chlorine 35.5	35	ğ	bromine 79.9	53	Ι	iodine 126.9	85	Ą	astatine -				
	16			8	0	oxygen 16.0	16	ഗ	sulfur 32.1	34	Se	selenium 79.0	52	<u>e</u>	tellurium 127.6	84	Ъ	polonium –	116		livermorium —	
	15			7	z	nitrogen 14.0	15	۵	phosphorus 31.0	33	As	arsenic 74.9	51	Sp	antimony 121.8	83	ï	bismuth 209.0				
	4			9	ပ	carbon 12.0	14	:S	silicon 28.1	32	Ge	germanium 72.6	20	Sn	tin 118.7	82	Pp	lead 207.2	114	Εl	flerovium	
	13			5	В	boron 10.8	13	Αl	aluminium 27.0	31	Ga	gallium 69.7	49	In	indium 114.8	81	lΤ	thallium 204.4				
									12	30	Zu	zinc 65.4	48	g	cadmium 112.4	80	Ε̈́	mercury 200.6			0	
									1	29	Cn	copper 63.5	47	Ag	silver 107.9	62	Au	gold 197.0	111	Rg	roentgenium -	
Group									10	28	Ż	nickel 58.7	46	Pd	palladium 106.4	78	Ŧ	platinum 195.1	110	Ds	darmstadtium -	
Gre									6	27	රි	cobalt 58.9	45	格	rhodium 102.9	77	I	iridium 192.2	109	¥	meitnerium -	
		- I	hydrogen 1.0						80	26	Pe	iron 55.8	44	Ru	ruthenium 101.1	92	SO	osmium 190.2	108	Η̈́	hassium -	
									7	22	Mn	manganese 54.9	43	ည	technetium -	75	Re	rhenium 186.2	107	В	bohrium –	
					_	pol	ass			9	24	ပ်	chromium 52.0	42	Mo	molybdenum 95.9	74	>	tungsten 183.8	106	Sg	seaborgium
			Key	atomic number	atomic symbo	name relative atomic mass			2	23	>	vanadium 50.9	41	q	niobium 92.9	73	<u>ra</u>	tantalum 180.9	105	Op	dubnium -	
					atc	rel			4	22	j	titanium 47.9	40	Zr	zirconium 91.2	72	Ξ	hafnium 178.5	104	꿒	rutherfordium -	
									ဇ	21	လွ	scandium 45.0	39	>	yttrium 88.9	57-71	lanthanoids		89–103	actinoids		
	2			4	Be	beryllium 9.0	12	Mg	magnesium 24.3	20	Ca	calcium 40.1	38	Š	strontium 87.6	56	Ва	barium 137.3	88	Ra	radium	
	_			က	<u></u>	lithium 6.9	=	Na	sodium 23.0	19	¥	potassium 39.1	37	Rb	rubidium 85.5	55	S	caesium 132.9	87	占	francium —	

71 Lu Iutetium 175.0	103 Lr lawrencium
70 Yb ytterbium 173.1	No nobelium
69 Tm thulium 168.9	Md mendelevium
68 Er erbium 167.3	100 Fm fermium
67 Ho holmium 164.9	BS einsteinium
66 Dy dysprosium 162.5	98 Cf californium
65 Tb terbium 158.9	97 Bk berkelium
Gd gadolinium 157.3	Om curium
63 Eu europium 152.0	95 Am americium
62 Sm samarium 150.4	94 Pu plutonium
61 Pm promethium	93 Np neptunium
60 Nd neodymium 144.4	92 Uranium 238.0
59 Pr praseodymium 140.9	Pa protactinium 231.0
58 Ce cerium 140.1	90 Th thorium 232.0
57 La lanthanum 138.9	89 AC actinium

lanthanoids

actinoids

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