Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

8231388626

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **October/November 2023**

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.

DC (PQ) 311005/3

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 You will carry out a titration to determine the concentration of a solution of potassium manganate(VII), $KMnO_4$. Potassium manganate(VII) reacts with excess acidified potassium iodide to produce iodine. This iodine is titrated with aqueous sodium thiosulfate.

FA 1 is aqueous potassium manganate(VII), $KMnO_4$.
FA 2 is 0.500 mol dm^{-3} potassium iodide, KI.
FA 3 is 0.120 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 4 is dilute sulfuric acid, H_2SO_4.
FA 5 is starch indicator.

(a) Method

Titration

- Fill the burette with **FA 3**.
- Pipette 25.0 cm^3 of **FA 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10.0 cm^3 of **FA 2** to the conical flask.
- Use the 50 cm^3 measuring cylinder to add 15.0 cm^3 of **FA 4** to the conical flask.
- Perform a rough titration by adding **FA 3** from the burette to the conical flask until the solution is yellow.
- Then add several drops of **FA 5**. Continue the titration until the mixture in the flask becomes colourless. This is the end-point.
- Record the initial and final 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 3** added in each accurate titration.

Keep FA 2 and FA 5 for use in Question 3(b).

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 the mean value.

The iodine produced by **FA 1** required .... cm^3 of **FA 3**. [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 sodium thiosulfate in the volume of **FA 3** calculated in **(b)**.

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

(iii) The reaction by which iodine is produced is shown.

$$2KMnO_4(aq) + 10KI(aq) + 8H_2SO_4(aq) \rightarrow 6K_2SO_4(aq) + 2MnSO_4(aq) + 5I_2(aq) + 8H_2O(l)$$

During the titration, sodium thiosulfate reacts with the iodine produced.

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

Calculate the concentration of potassium manganate(VII), in $mol\,dm^{-3}$, in **FA 1**.

concentration of $KMnO_4$ = ... $mol\,dm^{-3}$ [2]

(iv) A laboratory technician purchased a bottle containing 50.00 g of potassium manganate(VII), $KMnO_4$, for this practical examination. Using your answer to **(c)(iii)**, calculate the maximum volume of **FA 1**, in dm^3, that the technician can prepare using the contents of this bottle.

volume of **FA 1** = ... dm^3 [1]

(d) A student suggested that the accuracy of the experiment would be increased by using a 10 cm^3 pipette to measure **FA 2**.
State whether the student is correct. Explain your answer.

....

.... [1]

[Total: 14]

2 You will determine the enthalpy change for the reaction of magnesium oxide with water to form magnesium hydroxide.

$$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$$

The procedure will involve two experiments, one with magnesium oxide and the other with magnesium hydroxide. In each case you will react the solid with hydrochloric acid.

FA 6 is magnesium oxide, MgO.
FA 7 is 2.0 mol dm^{-3} hydrochloric acid, HCl.
FA 8 is magnesium hydroxide, $Mg(OH)_2$.

(a) **Experiment 1** is the determination of the enthalpy change of reaction, ΔH_1, of magnesium oxide with hydrochloric acid.

$$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$$

(i) **Method**

- Support a cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 30.0 cm^3 of **FA 7** into the cup.
- Measure and record the temperature of the solution in the cup.
- Weigh the container with **FA 6**. Record the mass.
- Tip all of **FA 6** into the cup containing **FA 7**. **FA 7** is in excess.
- Stir the mixture until the maximum temperature is obtained. Record the maximum temperature.
- Weigh the container with any residual **FA 6**. Record the mass.
- Calculate and record the mass of **FA 6** used.
- Calculate and record the temperature rise.

I	
II	
III	

[3]

(ii) Calculate the energy released in your experiment.

energy released = ... J [1]

(iii) Calculate the enthalpy change of reaction, ΔH_1, in $kJ\,mol^{-1}$ of $MgO(s)$, for the reaction of magnesium oxide with hydrochloric acid.
Show your working.

ΔH_1 = ... $kJ\,mol^{-1}$
sign *value* [2]

(b) **Experiment 2** is the determination of the enthalpy change of the reaction, ΔH_2, of magnesium hydroxide with hydrochloric acid.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

(i) **Method**

- Place the other cup in the beaker.
- Use the $50\,cm^3$ measuring cylinder to transfer $30.0\,cm^3$ of **FA 7** into the cup.
- Measure and record the temperature of the solution in the cup.
- Weigh the container with magnesium hydroxide, **FA 8**. Record the mass.
- Tip all of **FA 8** into the cup containing **FA 7**. **FA 8** is in excess.
- Stir the mixture until the maximum temperature is obtained. Record the maximum temperature.
- Weigh the container with any residual **FA 8**. Record the mass.
- Calculate and record the mass of **FA 8** used.
- Calculate and record the temperature rise.

I	
II	
III	

[3]

(ii) Calculate the enthalpy change of reaction, ΔH_2, in $kJ\,mol^{-1}$ of $Mg(OH)_2(s)$, for the reaction of magnesium hydroxide with hydrochloric acid.
Show your working.

ΔH_2 = ... $kJ\,mol^{-1}$
sign *value* [2]

(c) Use your answers to **(a)(iii)** and **(b)(ii)** to calculate the enthalpy change, ΔH_r, in $kJ\,mol^{-1}$, for the reaction between magnesium oxide and water. The equation for the reaction is shown.

$$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$$

Show your working.

ΔH_r = ... $kJ\,mol^{-1}$
sign *value* [1]

[Total: 12]

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 **FA 9** contains one cation and one anion. The cation is one of calcium, magnesium, manganese(II) or zinc. The anion is oxide or carbonate.

(a) Describe reactions to identify **FA 9**. You are advised to test for the anion first.
State any conditions needed for these reactions.

Carry out your reactions and record all your observations.
Deduce the formula of **FA 9**.

FA 9 is .... [4]

(b) **(i)** **FA 10** is a solution of a double salt. It contains two cations and one anion, all of which are listed in the Qualitative analysis notes.
Use a 1 cm depth of this solution of **FA 10** in a test-tube for Tests 1–3.

Table 3.1

test	*observations*
Test 1 Add an equal volume of **FA 2**, aqueous potassium iodide, then	
add **FA 5**, aqueous starch.	
Test 2 Add aqueous barium chloride (or barium nitrate), then	
add dilute hydrochloric acid (or nitric acid).	
Test 3 Add aqueous silver nitrate, then	
add aqueous ammonia.	
Test 4 In a boiling tube, add aqueous sodium hydroxide to a 1 cm depth of solution of **FA 10**, then	
warm gently and carefully, then	
remove from heat and add one piece of aluminium foil to the mixture.	

[5]

(ii) Identify the three ions in **FA 10** by writing the formula of each ion.

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

(iii) Identify the **two** tests in **(b)(i)** that involve redox reactions.
Justify your answer for **one** of the tests.

Tests .... and .... involve redox reactions.

justification ....

....

.... [2]

(iv) Give an ionic equation for the reaction of **one** of the ions in **FA 10** with sodium hydroxide in **Test 4**. Include state symbols.

.... [1]

[Total: 14]

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	$V_m = 22.4\,dm^3\,mol^{-1}$ 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 A*l* aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 C*l* 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 T*l* 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 F*l* 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 –