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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER				

* 7 0 9 0 1 7 5 5 1 4 *

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **May/June 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	

This document has **16** pages. Any blank pages are indicated.

[Turn over

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 answer to **each** step of your calculations.

1 Hydrogen peroxide, H_2O_2, reacts rapidly with acidified potassium manganate(VII), $KMnO_4$.

$$5H_2O_2(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 5O_2(g) + 8H_2O(l) + 2Mn^{2+}(aq)$$

You will determine the concentration of a solution of hydrogen peroxide. You will first dilute the solution and then carry out a titration with acidified potassium manganate(VII).

FA 1 is aqueous hydrogen peroxide, H_2O_2.
FA 2 is 0.0300 mol dm^{-3} potassium manganate(VII), $KMnO_4$.
FA 3 is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4.

(a) Method

Dilution of **FA 1**

- Pipette 25.0 cm^3 of **FA 1** into the 250 cm^3 volumetric flask.
- Add distilled water to make 250 cm^3 of solution.
- Shake the flask thoroughly.
- Label this diluted solution of hydrogen peroxide **FA 4**.

Titration

- Fill the burette with **FA 2**.
- Rinse the 25.0 cm^3 pipette with distilled water and then with **FA 4**.
- Pipette 25.0 cm^3 of **FA 4** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 of **FA 3** to the conical flask.
- Perform 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 your recorded results show the precision of your practical work.
- Record, in a suitable form in the space for results, all your burette readings and the volume of **FA 2** added in each accurate titration.

Keep FA 1 for use in Questions 2 and 3.
Keep FA 2 for use in Question 3.

DO NOT WRITE IN THIS MARGIN

Results

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, calculate a suitable mean value to use in your calculations. Show clearly how you obtain the mean value.

25.0 cm^3 of **FA 4** 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 amount, in mol, of manganate(VII) ions in the volume of **FA 2** in **(b)**.

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

(iii) Calculate the amount, in mol, of hydrogen peroxide in 25.0 cm^3 of **FA 4**.

amount of H_2O_2 = ... mol [1]

(iv) Calculate the concentration, in mol dm^{-3}, of hydrogen peroxide in **FA 1**.

concentration of H_2O_2 in **FA 1** = ... mol dm^{-3} [1]

(d) A student suggests that the experiment would be more accurate if a 10 cm^3 pipette is used to measure **FA 3** in place of the measuring cylinder.

State whether the student's suggestion is correct. Explain your answer.
Include a calculation as part of your explanation.

....

....

....
[2]

[Total: 14]

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2 You will now determine the concentration of a solution of hydrogen peroxide by a different method.

Hydrogen peroxide decomposes slowly into water and oxygen at room temperature. This reaction is exothermic. When a catalyst is added, the decomposition is fast and there is a measurable temperature rise.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g) \qquad \Delta H = -98.2\,kJ\,mol^{-1}$$

FA 1 is aqueous hydrogen peroxide, H_2O_2.
FA 5 is manganese(IV) oxide, MnO_2.

(a) Method

Experiment 1

- Support one of the cups in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 25.0 cm^3 of **FA 1** to the cup.
- Place the thermometer in the **FA 1** and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature in the space for results.
- Add a heaped spatula measure of **FA 5** to the solution in the cup.
- Stir constantly until the maximum temperature is reached. Record this temperature.
- Calculate and record the temperature rise.
- Rinse and dry the thermometer.

Experiment 2

- Support the second cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to add 40.0 cm^3 of **FA 1** to the second cup.
- Measure and record the initial temperature of the solution.
- Add a heaped spatula measure of **FA 5** to the solution in the second cup.
- Stir constantly until the maximum temperature is reached. Record this temperature.
- Calculate and record the temperature rise.

Keep FA 5 for use in Question 3.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

(i) Calculate the energy change, in J, in **Experiment 2**.

energy change = ... J [1]

(ii) Use the information given and your answer to **(b)(i)** to calculate the concentration, in $mol\,dm^{-3}$, of hydrogen peroxide in **FA 1**.

concentration of H_2O_2 in **FA 1** = ... $mol\,dm^{-3}$ [2]

(c) The concentration of hydrogen peroxide in **FA 1** calculated using the method given for Question 1 is more accurate than that using the method given for Question 2.

(i) Heat loss is a large source of error when carrying out the method for Question 2. Describe and explain the effect of heat loss on the value of the concentration of hydrogen peroxide calculated.

....

....

.... [1]

(ii) A student suggests that calculating the concentration of hydrogen peroxide using the method in Question 2 would be less accurate when the concentration is lower.
Suggest whether the student is correct. Explain your answer.

....

.... [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. 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)** **(i)** Transfer a 2 cm depth of **FA 2**, $KMnO_4$, into a test-tube. Add the same volume of aqueous sodium hydroxide followed by a small spatula measure of **FA 5**, MnO_2. Stir for approximately 30 seconds then filter the mixture into a second test-tube.

observations ....

....

Add dilute sulfuric acid to the filtrate until no further change.

observations ....

....

[2]

(ii) Transfer a 1 cm depth of aqueous iron(II) sulfate into a boiling tube. Add the same depth of dilute sulfuric acid followed by a very small spatula measure of **FA 5**, MnO_2. Carefully warm the mixture using a Bunsen burner for about 20 seconds. Filter the warm mixture into a test-tube.

observations ....

....

Add aqueous sodium hydroxide dropwise to the filtrate until no further change.

observations ....

....

[2]

(iii) Suggest a conclusion about the chemical behaviour of **FA 5** using your observations in **(a)(ii)**.

FA 5 is acting as .... [1]

(iv) Write an ionic equation for the reaction between aqueous sodium hydroxide and the filtrate in **(a)(ii)**. Include state symbols.

.... [1]

Question 3 continues on page 10.

(b) **FA 6** and **FA 7** are both aqueous solutions of salts. Neither solution includes an ion that contains sulfur.

FA 6 contains two cations and one anion. Two of the ions are listed in the Qualitative analysis notes.
FA 7 contains one cation and one anion. One of the ions is listed in the Qualitative analysis notes.

(i) Carry out the following tests and record your observations in Table 3.1.
Use a 1 cm depth of **FA 6** or **FA 7** in a boiling tube for Test 1. Use a 1 cm depth of **FA 6** or **FA 7** in a test-tube for Tests 2, 3 and 4.

Table 3.1

test	*observations*	
	FA 6	**FA 7**
Test 1 Add aqueous sodium hydroxide, then		
warm gently.		
Test 2 Add acidified aqueous $KMnO_4$ dropwise until no further change.		
Test 3 Add an equal volume of **FA 1**, H_2O_2, then	(crossed out)	
add a few drops of starch solution.	(crossed out)	
Test 4 Add aqueous sodium carbonate.		

[6]

(ii) The anion in **FA 6** does **not** contain nitrogen. Select **one** further reagent to identify the anion present in **FA 6**.
Carry out a test with this reagent and record your observations in Table 3.2.

Table 3.2

reagent	*observations*

[1]

(iii) Give the formulae of the ions present in **FA 6** and **FA 7**. If you are unable to identify an ion from your tests, write 'unknown.'

The ions present in **FA 6** are .... and .... and ....

The ions present in **FA 7** are .... and ....

[3]

[Total: 16]

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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	$L = 6.02 \times 10^{23}\,mol^{-1}$
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

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 144.2	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 –