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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

6062713643

CHEMISTRY **9701/38**

Paper 3 Advanced Practical Skills 2 **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 **12** pages.

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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 Iron is an element that is essential in the human diet. Some people need to take iron supplement tablets to ensure an adequate intake of iron.

You will investigate the mass of iron in an iron supplement tablet by titrating a solution with potassium manganate(VII).

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

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

FB 1 is an aqueous solution of iron supplement tablets made by dissolving 14 tablets in 1.00 dm^3 of solution. The iron in each tablet is iron(II) sulfate, $FeSO_4 \bullet 7H_2O$.
FB 2 is 0.0100 mol dm^{-3} acidified aqueous potassium manganate(VII), $KMnO_4$.
FB 3 is dilute sulfuric acid, H_2SO_4.

(a) Method

- Fill a burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 1** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10.0 cm^3 of **FB 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 any recorded results show the precision of your practical work.
- Record, in a suitable form in the space below, all your burette readings and the volume of **FB 2** added in each accurate titration.

Rinse the burette with distilled water and leave to drain while you continue Question 1.

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 **FB 1** required .... cm^3 of **FB 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 **FB 2** in **(b)**.

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

(iii) Use your answer to **(c)(ii)** and the equations at the start of the question to calculate the concentration, in $mol\,dm^{-3}$, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = ... $mol\,dm^{-3}$ [1]

(iv) Use your answer to **(c)(iii)** to calculate the concentration, in $g\,dm^{-3}$, of iron(II) ions in **FB 1**.

concentration of Fe^{2+} = ... $g\,dm^{-3}$ [1]

(v) The manufacturer of the iron supplement tablets used to make **FB 1** claims that each tablet contains a minimum of 150 mg of Fe^{2+}.

Use your answer to **(c)(iv)** and the information given about **FB 1** to determine whether this claim is correct. Show your working.

[1]

(d) A student used all the **FB 3** and suggests that dilute hydrochloric acid would be a suitable replacement.
Suggest whether the student is correct or not. Explain your answer.

....

....

.... [1]

[Total:14]

2 The reaction between an acid and an alkali is exothermic. You will carry out a neutralisation experiment to determine the enthalpy change involved.

You will mix different volumes of an acid with a fixed volume of an alkali and measure the temperature rises that occur.

FB 4 is aqueous sodium hydroxide, NaOH.
FB 5 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

- Use the thermometer to measure the initial temperature of **FB 4**. Record this initial temperature in the space for results.
- Support the cup in the 250 cm^3 beaker.
- Fill one burette with **FB 5**. Label the burette **FB 5**.
- Fill the other burette with distilled water.

Experiment 1

- Use the 10 cm^3 pipette to transfer 10.0 cm^3 of **FB 4** into the cup.
- Add 9.00 cm^3 of distilled water from the burette to the same cup.
- Add 1.00 cm^3 of **FB 5** from the other burette to the same cup.
- Stir the mixture and use the thermometer to measure the maximum temperature. If necessary, tilt the cup so that the solution covers the bulb of the thermometer.
- Record the maximum temperature in Table 2.1.
- Empty, rinse and dry the cup ready for use in further experiments.

Further experiments

Repeat this method for Experiments 2–5, using 10.0 cm^3 of **FB 4** and the volumes of water and **FB 5** shown in Table 2.1. In each case, measure and record the maximum temperature.

Carry out **two** further experiments, Experiments 6 and 7, which will enable you to determine more precisely the volume of **FB 5** that gives the largest maximum temperature. Record your measurements in Table 2.1.

Results

initial temperature of **FB 4** = ... °C

Table 2.1

experiment	volume of water / cm^3	volume of **FB 5** / cm^3	maximum temperature / °C
1	9.00	1.00	
2	7.00	3.00	
3	5.00	5.00	
4	3.00	7.00	
5	1.00	9.00	
6			
7			

I	
II	
III	
IV	

[4]

(b) **(i)** Plot a graph of the maximum temperature (*y*-axis) against the volume of **FB 5** (*x*-axis) on the grid. The scale on the *y*-axis should be suitable for temperature readings to be 2 °C above the largest maximum temperature.

Label any points you consider to be anomalous.

Draw **two** lines of best fit, the first for the increase in maximum temperature and the second for after the largest maximum temperature has been reached. Extrapolate both lines so that they intersect.

[4]

I		II		III		IV	

(ii) Use the intersection on your graph in **(b)(i)** to determine the volume of **FB 5** required to neutralise 10.0 cm^3 of **FB 4**.

volume of **FB 5** = ... cm^3 [1]

(c) Calculations

(i) Calculate the amount, in mol, of hydrochloric acid in the volume of **FB 5** in **(b)(ii)**.

(If you were unable to determine an answer to **(b)(ii)**, use 5.10 cm^3 as the volume of **FB 5**. This may **not** be the correct answer.)

amount of HCl = ... mol

Deduce the amount, in mol, of sodium hydroxide in 10.0 cm^3 of **FB 4**.

amount of NaOH = ... mol
[1]

(ii) Calculate the energy change, in J, when the amounts of reagents in **(c)(i)** neutralise each other. Show your working.

energy change = ... J [1]

(iii) Use your answer to **(c)(ii)** to calculate the enthalpy change, in $kJ\,mol^{-1}$, when one mole of **FB 4** is neutralised by one mole of **FB 5**.

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

[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. 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) **FB 6**, **FB 7** and **FB 8** are aqueous solutions of different compounds that each contain at least one oxygen atom.

Carry out the following tests and record your observations in Table 3.1. Three of the tests have been done for you. Use a 1 cm depth of solution in a test-tube for each test.

Table 3.1

test	*observations*		
	FB 6	**FB 7**	**FB 8**
Test 1 Add a small spatula measure of manganese(IV) oxide.	No change.	No change.	
Test 2 Add a 1 cm length of magnesium.			No change.
Test 3 Add a few drops of aqueous iron(II) sulfate.			

[4]

DO NOT WRITE IN THIS MARGIN

(ii) Use your observations in Table 3.1 to suggest a possible formula for each of **FB 6**, **FB 7** and **FB 8**.

FB 6 ....

FB 7 ....

FB 8 ....

[2]

(b) **FB 9** contains two anions and two cations, three of which are listed in the Qualitative analysis notes.

(i) To a small spatula measure of **FB 9** in a test-tube, add a 2 cm depth of dilute nitric acid. Record your observations.

Keep the resulting solution for the test in (b)(ii).

....

....

.... [2]

(ii) To the solution from **(b)(i)**, add a few drops of aqueous silver nitrate. Then add excess aqueous ammonia. Record your observations.

....

....

.... [1]

(iii) Make an aqueous solution of **FB 9** by adding a 5 cm depth of distilled water to a spatula measure of **FB 9** in a test-tube. Carry out the following tests on the aqueous solution of **FB 9** and record your observations in Table 3.2.

Table 3.2

test	*observations*
Test 1 To a 1 cm depth in a boiling tube, add aqueous sodium hydroxide, then	
warm.	
Test 2 To a 1 cm depth in a test-tube, add a few drops of dilute hydrochloric acid, then add a few drops of aqueous chlorine. **Empty and rinse the test-tube with water immediately after use.**	

[2]

(iv) Use your observations in **(b)(i)**, **(b)(ii)** and Table 3.2 to deduce the formulae of the cations and anions in **FB 9**. If you are unable to identify an ion, write 'unknown'.

cations .... and ....

anions .... and ....

[2]

(v) Write an ionic equation for the reaction in **(b)(ii)**. 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	$L = 6.02 \times 10^{23}\,mol^{-1}$
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 –