Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

0128209116

CHEMISTRY **9701/32**

Paper 3 Advanced Practical Skills 2 **May/June 2024**

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.

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 Students are told to plan and carry out an experiment to determine the enthalpy change, ΔH_1, when one mole of anhydrous sodium thiosulfate, $Na_2S_2O_3$, is hydrated.

$$Na_2S_2O_3(s) + 5H_2O(l) \rightarrow Na_2S_2O_3{\bullet}5H_2O(s)$$

One student suggested adding five moles of water to one mole of anhydrous sodium thiosulfate and measuring the temperature change.

Their teacher said that method would **not** work and suggested another method using Hess's law.

You will carry out the teacher's method to determine the enthalpy change, ΔH_2, when one mole of hydrated sodium thiosulfate, $Na_2S_2O_3{\bullet}5H_2O$, is dissolved in water.

$$Na_2S_2O_3{\bullet}5H_2O(s) + \text{water} \rightarrow Na_2S_2O_3(aq)$$

You will do this by adding a known mass of hydrated sodium thiosulfate to a known volume of water and measuring the temperature change when the solid dissolves.

(a) Explain why the student's suggestion to add five moles of water to one mole of anhydrous sodium thiosulfate would **not** be a suitable method to determine ΔH_1.

....

.... [1]

(b) **Teacher's method**

FB 1 is hydrated sodium thiosulfate, $Na_2S_2O_3{\bullet}5H_2O$.

- Support the cup in the 250 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to transfer 25.0 cm^3 of distilled water into the cup.
- Place the thermometer in the water and tilt the cup, if necessary, so that the bulb of the thermometer is fully covered. Record the temperature of the water in the space for results.
- Weigh the container with **FB 1**. Record the mass.
- Add all of the **FB 1** to the water in the cup.
- Stir the mixture. Measure and record the minimum temperature reached.
- Reweigh the container and any residual **FB 1**. Record the mass.
- Calculate and record the mass of **FB 1** added.
- Calculate and record the change in temperature.

Results

I	
II	
III	
IV	

[4]

(c) Calculations

(i) Calculate the energy change, in J, when **FB 1** is added to water.

energy change = ... J [1]

(ii) Calculate the enthalpy change, ΔH_2, in $kJ\,mol^{-1}$, when one mole of hydrated sodium thiosulfate, **FB 1**, dissolves in water.

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

(iii) The enthalpy change, ΔH_3, when one mole of anhydrous sodium thiosulfate is dissolved in water is $-8.1\,kJ\,mol^{-1}$.

$$Na_2S_2O_3(s) + water \rightarrow Na_2S_2O_3(aq) \qquad \Delta H_3 = -8.1\,kJ\,mol^{-1}$$

Use your answer to **(c)(ii)** and the information given to construct a Hess's cycle to calculate ΔH_1 in $kJ\,mol^{-1}$. Show clearly how you used the data.

(If you were unable to calculate an answer in **(c)(ii)**, assume a value of $31.6\,kJ\,mol^{-1}$. Note this may **not** be the correct value and the sign has been omitted.)

$$Na_2S_2O_3(s) + 5H_2O(l) \rightarrow Na_2S_2O_3{\bullet}5H_2O(s) \qquad \Delta H_1$$

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

(d) A sample of **FB 1** was contaminated with anhydrous sodium thiosulfate.
State what effect this would have on the temperature change in **(b)**. Explain your answer.

....

....

.... [1]

[Total: 11]

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2 Iodate ions contain iodine and oxygen. They have the formula IO_x^- where *x* is an integer.

In this experiment you will determine the value of *x* in an iodate. You will first react IO_x^- with an excess of iodide ions, I^-, to form iodine, I_2.

The amount of iodine produced is then determined by titration with thiosulfate ions, $S_2O_3^{2-}$.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

FB 2 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FB 3 is a solution containing 0.0140 mol dm^{-3} IO_x^- ions.
FB 4 is dilute sulfuric acid, H_2SO_4.
FB 5 is 0.500 mol dm^{-3} potassium iodide, KI.
FB 6 is starch indicator.

(a) Method

- Fill the burette with **FB 2**.
- Pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Use the 25 cm^3 measuring cylinder to add 10 cm^3 of **FB 4** to the conical flask.
- Use the same measuring cylinder to add 10 cm^3 of **FB 5** to the conical flask.
- Add **FB 2** from the burette until the solution turns yellow.
- Add 10–15 drops of **FB 6** to the solution in the conical flask.
- Continue to add more **FB 2** from the burette until the blue-black colour just disappears.
- 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.

Keep the remaining FB 2 for use in Question 3.

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 3** 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) Use your answer to **(b)** and the information given to calculate the amount, in mol, of iodine formed when 25.0 cm^3 of **FB 3** reacts with 10 cm^3 of **FB 5**.

amount of I_2 = ... mol [1]

(iii) Calculate the amount, in mol, of IO_x^- ions in 25.0 cm^3 of **FB 3**.

amount of IO_x^- ions = ... mol [1]

(iv) An unbalanced equation for the reaction of IO_x^- ions with iodide ions, I^-, and hydrogen ions, H^+, is shown.

$$IO_{....}^{-} + ...\ I^- + ...\ H^+ \rightarrow ....\ I_2 + ...\ H_2O$$

Use the ratio of your answers to **(c)(ii)** and **(c)(iii)** to balance this equation and determine the value of *x*.
Show your working.

ratio IO_x^- : I_2 = 1 : ....

x = ...
[2]

(d) A student carries out the same experiment as in **(a)** but uses 0.0140 mol dm^{-3} IO_2^- ions in place of **FB 3**.

Tick the correct box in Table 2.1. Explain your answer.

(If you were unable to determine the value of *x* in **(c)(iv)** or you determined the value of *x* to be 2, assume *x* = 4. Note that this may **not** be the correct value).

Table 2.1

Volume of **FB 2** will be smaller.	
Volume of **FB 2** will be unchanged.	
Volume of **FB 2** will be larger.	

....

....

....
[2]

[Total: 15]

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[Turn over

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 **FB 7** is an aqueous solution of a salt containing one cation and one anion, both of which are listed in the Qualitative analysis notes.

(a) (i) Carry out the following tests using a 1 cm depth of **FB 7** in a test-tube for each test.
Record your observations in Table 3.1.

Table 3.1

test	*observations*
Test 1 Add aqueous barium chloride or aqueous barium nitrate.	
Test 2 Add aqueous sodium hydroxide, then	
transfer the mixture to a boiling tube and warm gently, then	
add a small piece of aluminium foil.	
Test 3 Add aqueous ammonia.	

[4]

(ii) The results of the tests in Table 3.1 allow you to deduce **one** cation and **two** possible anions in **FB 7**.

Deduce which ions may be present in **FB 7**. Give the formulae of the ions.

cation ....

anion .... or ....

[2]

(iii) Describe a test to identify which of the possible anions is present in **FB 7**.

Carry out your test. Record your observations and conclusion.

test ....

....

observations ....

conclusion ....

[2]

Question 3 continues on page 12.

(b) (i) **FB 8** and **FB 9** are solutions of Group 1 salts. Each contains one anion, both of which are listed in the Qualitative analysis notes. One of the anions contains oxygen but **not** nitrogen. The other anion is a halide.

Carry out tests to identify the **two** anions. Record your tests and observations in a suitable form in the space below.

[4]

(ii) Use your observations in **(b)(i)** to complete Table 3.2 by identifying the formulae of the anions in **FB 8** and **FB 9**.

Table 3.2

	FB 8	**FB 9**
anion		

[1]

(iii) Write an ionic equation for a reaction observed in **(b)(i)** for **one** of the anions tested. Include state symbols.

.... [1]

[Total: 14]

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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 × 10^{4} C mol^{-1}
Avogadro constant	L = 6.022 × 10^{23} mol^{-1}
electronic charge	e = –1.60 × 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 × 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 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 –