



Cambridge International AS & A Level

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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.

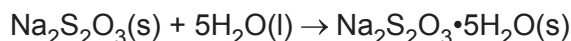
Quantitative analysis

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.

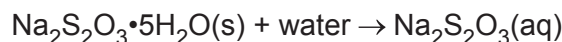
- 1 Students are told to plan and carry out an experiment to determine the enthalpy change, ΔH_1 , when one mole of anhydrous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, is hydrated.



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, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, is dissolved in water.



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, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

- Support the cup in the 250 cm³ beaker.
- Use the 25 cm³ measuring cylinder to transfer 25.0 cm³ 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

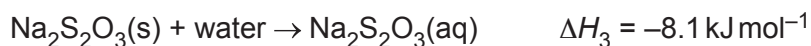
- (i) Calculate the energy change, in J, when **FB 1** is added to water.

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.

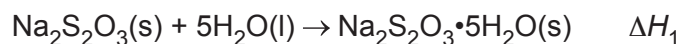
$\Delta H_2 = \underset{\text{sign}}{\text{.....}} \underset{\text{value}}{\text{.....}} \text{ kJ mol}^{-1}$ [2]

- (iii) The enthalpy change, ΔH_3 , when one mole of anhydrous sodium thiosulfate is dissolved in water is -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.)



$$\Delta H_1 = \underset{\text{sign}}{\dots} \underset{\text{value}}{\dots} \text{ kJ mol}^{-1} \quad [2]$$

- (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.

.....

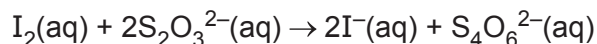
 [1]

[Total: 11]

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, $\text{S}_2\text{O}_3^{2-}$.



FB 2 is $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

FB 3 is a solution containing $0.0140 \text{ mol dm}^{-3}$ IO_x^- ions.

FB 4 is dilute sulfuric acid, H_2SO_4 .

FB 5 is $0.500 \text{ mol dm}^{-3}$ 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 cm³ of **FB 3** required cm³ of **FB 2**. [1]

(c) **Calculations**

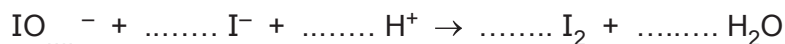
- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to an appropriate number of significant figures. [1]
- (ii) Use your answer to (b) and the information given to calculate the amount, in mol, of iodine formed when 25.0 cm³ of **FB 3** reacts with 10 cm³ of **FB 5**.

amount of I₂ = mol [1]

- (iii) Calculate the amount, in mol, of IO_x⁻ ions in 25.0 cm³ 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.



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⁻ : I₂ = 1 :

x =

[2]

- (d) A student carries out the same experiment as in (a) but uses $0.0140 \text{ mol dm}^{-3} \text{ IO}_2^-$ 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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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

<i>test</i>	<i>observations</i>
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]

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 ₂ O 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	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (4.18 J g ⁻¹ K ⁻¹)

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">1 H hydrogen 1.0</div> <div style="border: 1px solid black; padding: 5px;">2 He helium 4.0</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">3 Li lithium 6.9</div> <div style="border: 1px solid black; padding: 5px;">4 Be beryllium 9.0</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">5 B boron 10.8</div> <div style="border: 1px solid black; padding: 5px;">6 C carbon 12.0</div> <div style="border: 1px solid black; padding: 5px;">7 N nitrogen 14.0</div> <div style="border: 1px solid black; padding: 5px;">8 O oxygen 16.0</div> <div style="border: 1px solid black; padding: 5px;">9 F fluorine 19.0</div> <div style="border: 1px solid black; padding: 5px;">10 Ne neon 20.2</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">11 Na sodium 23.0</div> <div style="border: 1px solid black; padding: 5px;">12 Mg magnesium 24.3</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">13 Al aluminium 27.0</div> <div style="border: 1px solid black; padding: 5px;">14 Si silicon 28.1</div> <div style="border: 1px solid black; padding: 5px;">15 P phosphorus 31.0</div> <div style="border: 1px solid black; padding: 5px;">16 S sulfur 32.1</div> <div style="border: 1px solid black; padding: 5px;">17 Cl chlorine 35.5</div> <div style="border: 1px solid black; padding: 5px;">18 Ar argon 39.9</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">19 K potassium 39.1</div> <div style="border: 1px solid black; padding: 5px;">20 Ca calcium 40.1</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">21 Sc scandium 45.0</div> <div style="border: 1px solid black; padding: 5px;">22 Ti titanium 47.9</div> <div style="border: 1px solid black; padding: 5px;">23 V vanadium 50.9</div> <div style="border: 1px solid black; padding: 5px;">24 Cr chromium 52.0</div> <div style="border: 1px solid black; padding: 5px;">25 Mn manganese 54.9</div> <div style="border: 1px solid black; padding: 5px;">26 Fe iron 55.8</div> <div style="border: 1px solid black; padding: 5px;">27 Co cobalt 58.9</div> <div style="border: 1px solid black; padding: 5px;">28 Ni nickel 58.7</div> <div style="border: 1px solid black; padding: 5px;">29 Cu copper 63.5</div> <div style="border: 1px solid black; padding: 5px;">30 Zn zinc 65.4</div> <div style="border: 1px solid black; padding: 5px;">31 Ga gallium 69.7</div> <div style="border: 1px solid black; padding: 5px;">32 Ge germanium 72.6</div> <div style="border: 1px solid black; padding: 5px;">33 As arsenic 74.9</div> <div style="border: 1px solid black; padding: 5px;">34 Se selenium 79.0</div> <div style="border: 1px solid black; padding: 5px;">35 Br bromine 79.9</div> <div style="border: 1px solid black; padding: 5px;">36 Kr krypton 83.8</div> </div>															
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		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">57–71 lanthanoids</div> <div style="border: 1px solid black; padding: 5px;">72 Hf hafnium 178.5</div> <div style="border: 1px solid black; padding: 5px;">73 Ta tantalum 180.9</div> <div style="border: 1px solid black; padding: 5px;">74 W tungsten 183.8</div> <div style="border: 1px solid black; padding: 5px;">75 Re rhenium 186.2</div> <div style="border: 1px solid black; padding: 5px;">76 Os osmium 190.2</div> <div style="border: 1px solid black; padding: 5px;">77 Ir iridium 192.2</div> <div style="border: 1px solid black; padding: 5px;">78 Pt platinum 195.1</div> <div style="border: 1px solid black; padding: 5px;">79 Au gold 197.0</div> <div style="border: 1px solid black; padding: 5px;">80 Hg mercury 200.6</div> <div style="border: 1px solid black; padding: 5px;">81 Tl thallium 204.4</div> <div style="border: 1px solid black; padding: 5px;">82 Pb lead 207.2</div> <div style="border: 1px solid black; padding: 5px;">83 Bi bismuth 209.0</div> <div style="border: 1px solid black; padding: 5px;">84 Po polonium —</div> <div style="border: 1px solid black; padding: 5px;">85 At astatine —</div> <div style="border: 1px solid black; padding: 5px;">86 Rn radon —</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">87 Fr francium —</div> <div style="border: 1px solid black; padding: 5px;">88 Ra radium —</div> </div>															
		<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="border: 1px solid black; padding: 5px;">89–103 actinoids</div> <div style="border: 1px solid black; padding: 5px;">104 Rf rutherfordium —</div> <div style="border: 1px solid black; padding: 5px;">105 Db dubnium —</div> <div style="border: 1px solid black; padding: 5px;">106 Sg seaborgium —</div> <div style="border: 1px solid black; padding: 5px;">107 Bh bohrium —</div> <div style="border: 1px solid black; padding: 5px;">108 Hs hassium —</div> <div style="border: 1px solid black; padding: 5px;">109 Mt meitnerium —</div> <div style="border: 1px solid black; padding: 5px;">110 Ds darmstadtium —</div> <div style="border: 1px solid black; padding: 5px;">111 Rg roentgenium —</div> <div style="border: 1px solid black; padding: 5px;">112 Cn copernicium —</div> <div style="border: 1px solid black; padding: 5px;">113 Nh nihonium —</div> <div style="border: 1px solid black; padding: 5px;">114 Fl flerovium —</div> <div style="border: 1px solid black; padding: 5px;">115 Mc moscovium —</div> <div style="border: 1px solid black; padding: 5px;">116 Lv livermorium —</div> <div style="border: 1px solid black; padding: 5px;">117 Ts tennessine —</div> <div style="border: 1px solid black; padding: 5px;">118 Og oganesson —</div> </div>															

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 —

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