Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

2788331627

CHEMISTRY **9701/33**

Paper 3 Advanced Practical Skills 1 **February/March 2024**

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions
Insert (enclosed)

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

1 The ionic equation for the reaction between sodium thiosulfate and hydrochloric acid is:

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq) + H_2O(l)$$

The solid sulfur formed causes the reaction mixture to become cloudy and opaque.

You will carry out experiments to investigate the relationship between the concentration of sodium thiosulfate and the rate of reaction.

Small amounts of SO_2 gas are released during this reaction. Take care to avoid inhaling this gas. It is important that, as soon as each experiment is complete, the contents of the beaker are emptied into the quenching bath and the beaker is rinsed thoroughly.

FA 1 is 0.10 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl.
distilled water

(a) Method

Prepare a table for your results in the Results section on page 4. For each experiment the table should include:

- volume of **FA 1** used
- volume of distilled water used
- reaction time
- relative rate.

Relative rate can be calculated using the expression:

$$\text{relative rate} = \frac{1000}{\text{reaction time}}$$

Experiment 1

- Label a burette **FA 1**. Fill the burette with **FA 1**.
- Transfer 25.00 cm^3 of **FA 1** into a 100 cm^3 beaker.
- Place the beaker on the printed insert.
- Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 2**.
- Add the **FA 2** to the **FA 1** in the beaker and immediately start the stop-clock. Stir the mixture once.
- Look vertically down through the solution in the beaker at the print on the insert.
- Stop the stop-clock as soon as the print on the insert is no longer visible.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse the beaker with water. Dry the beaker so that it is ready to be used in **Experiment 2**.

Experiment 2

- Transfer 12.50 cm^3 of **FA 1** into the 100 cm^3 beaker.
- Label a second burette 'water'. Fill this burette with distilled water.
- Transfer 12.50 cm^3 of distilled water into the 100 cm^3 beaker.
- Place the beaker on the printed insert.
- Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 2**.
- Add the **FA 2** to the solution in the beaker and immediately start the stop-clock. Stir the mixture once.
- Look vertically down through the solution in the beaker at the print on the insert.
- Stop the stop-clock as soon as the print on the insert is no longer visible.
- Record the reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse the beaker with water. Dry the beaker so that it is ready to be used in the next experiment.

Experiments 3–5

Carry out three further experiments to investigate how reaction times change with different volumes of **FA 1**. Do **not** use a volume of **FA 1** less than 12.50 cm^3.

Results

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) Plot a graph, on the grid, of relative rate (y-axis) against volume of **FA 1** (x-axis). The graph should **not** include the origin.

Identify any anomalous point.

Draw a line of best fit.

I	
II	
III	
IV	

[4]

(c) Use your graph to predict the reaction time if an experiment is carried out using 23.50 cm^3 of **FA 1** and distilled water.
Show clearly **on the grid** how you determined the relative rate.

reaction time = ... s
[2]

(d) The final instruction for each experiment is to rinse and dry the beaker.

State the effect on the reaction time of **not** drying the beaker before carrying out each of **Experiments 2–5**.
Explain your answer.

....

....

.... [1]

(e) A student repeats **Experiment 1** but uses a 250 cm^3 beaker in place of the 100 cm^3 beaker. All other conditions remain the same.

State whether each statement below is correct.
Explain your answers.

(i) The student records a longer time for this experiment because the 250 cm^3 beaker is used.

....

....

.... [1]

(ii) A longer time is recorded because the rate of production of sulfur is slower.

....

....

.... [1]

[Total: 17]

2 In this experiment you will determine the enthalpy change, ΔH, for the reaction between aqueous copper(II) sulfate and magnesium.

$$CuSO_4(aq) + Mg(s) \rightarrow Cu(s) + MgSO_4(aq)$$

FA 3 is 1.0 mol dm^{-3} copper(II) sulfate, $CuSO_4$.
FA 4 is magnesium powder, Mg.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Use the 50 cm^3 measuring cylinder to transfer 50.0 cm^3 of **FA 3** into the cup.
- Weigh the stoppered container of **FA 4**. Record the mass.
- Measure the temperature of **FA 3** in the cup. Record the temperature.
- Add the **FA 4** to the **FA 3** in the cup and stir the mixture constantly.
- Measure and record the maximum temperature reached.
- Reweigh the stoppered container and any residual **FA 4**. Record the mass.
- Calculate and record the mass of **FA 4** used.
- Calculate and record the maximum temperature change that occurs during the reaction.

[3]

(b) Calculations

(i) Calculate the heat energy produced in the reaction.

heat energy produced = ... J [1]

(ii) Determine which reactant, **FA 3** or **FA 4**, is in excess for the reaction.
Show your working.

[1]

(iii) Calculate the enthalpy change, ΔH, in $kJ\,mol^{-1}$, for the reaction.

ΔH = ... $kJ\,mol^{-1}$
(sign) (value)

[2]

(c) A student suggests that the slow rate of the reaction using the method described in **(a)** means that heat energy is lost from the solution so the temperature change is inaccurate.

Describe how you would change the method and processing of the results to improve the accuracy of the enthalpy change for this reaction. You should **not** change the quantities of **FA 3** or **FA 4** used.

You may wish to illustrate your answer with a sketch graph.

....

....

....

....

....

....

....

[3]

[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.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests should be attempted.

3 **(a)** Each of the solutions **FA 5**, **FA 6** and **FA 7** has an anion containing sulfur. All the anions are listed in the Qualitative analysis notes. None of the anions is present in more than one compound.
None of the solutions contain a cation listed in the Qualitative analysis notes.
Use 1 cm depth of each solution in a test-tube for each test. Record your observations in Table 3.1.

Table 3.1

test	*observations*		
	FA 5	**FA 6**	**FA 7**
Test 1 Add a few drops of aqueous acidified potassium manganate(VII) then			
leave it to stand for 2 minutes.			
Test 2 Add a piece of magnesium ribbon.			
Test 3 Add aqueous barium chloride or aqueous barium nitrate.			

[5]

(b) **(i)** Use your observations from **(a)** to identify the formula of each of the anions present in **FA 5**, **FA 6** and **FA 7**.

FA 5		**FA 6**		**FA 7**	

[2]

(ii) Use your observations from **(a)**, to suggest the identity of the cation present in **FA 6**.

The cation in **FA 6** is ....

Carry out a further test to check whether your suggestion is correct.
Record your test and observations.
State the identity of the cation in **FA 6**.

The cation in **FA 6** is ....

[2]

(c) Write an ionic equation for one of the reactions in either **Test 2** or **Test 3** in **(a)**. Include state symbols.

.... [1]

(d) **FA 8** is a solid compound.

(i) Gently warm (do **not** boil) a 4 cm depth of **FA 6** in a boiling tube. Stop warming the **FA 6**, add all the **FA 8** and shake the boiling tube.
Filter the mixture into a second boiling tube. The filtrate will be used in **(d)(ii)**.
Describe the appearance of the residue and the filtrate.

residue ....

filtrate ....

[1]

(ii) To a 2 cm depth of the filtrate from **(d)(i)** in a test-tube, add an equal volume of aqueous potassium iodide.
Record your observations. Filter the mixture into a test-tube for use in **(d)(iii)**.

....

.... [1]

(iii) To a 1 cm depth of the filtrate from **(d)(ii)**, add aqueous sodium hydroxide.
Record your observations.

....

.... [1]

[Total: 13]

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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	$L = 6.022 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ 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	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

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 144.4	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 –