Cambridge Assessment
International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

9446652702

CHEMISTRY **9701/31**

Paper 3 Advanced Practical Skills 1 **May/June 2023**

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.
- The insert contains additional resources referred to in the questions.

Session
Laboratory

For Examiner's Use	
1	
2	
3	
Total	

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

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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 The thiosulfate ion, $S_2O_3^{2-}$, decomposes when an acid is added.

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

The rate of this reaction can be investigated by measuring how long it takes the solution to produce enough sulfur so that it cannot be seen through.

You will investigate how the concentration of the thiosulfate ion affects the rate of the reaction.

Note: A small amount of sulfur dioxide gas may be formed in the experiment. It is very important that you avoid inhaling any fumes. As soon as each experiment is complete, empty the reaction mixture into the quenching bath and rinse the beaker thoroughly.

FA 1 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HCl.

(a) Method

Experiment 1

- Fill a burette with **FA 1**.
- Run 40.00 cm^3 of **FA 1** into the 100 cm^3 beaker.
- 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 start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above, through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second in the space for results on page 4.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker and glass rod so they are ready to use in Experiment 2.

Experiment 2

- Refill the burette with **FA 1**.
- Fill the other burette with distilled water.
- Run 20.00 cm^3 of **FA 1** into the 100 cm^3 beaker.
- Run 20.00 cm^3 of distilled water into the same beaker.
- 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 start timing **immediately**.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above, through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker and glass rod so they are ready to use in the next experiment.

Experiments 3–5

- Carry out **three** further experiments to investigate how using different volumes of **FA 1** affects the reaction time.

Note that the combined volumes of **FA 1** and distilled water must always be 40.00 cm^3.

Do **not** use a volume of **FA 1** that is less than 15.00 cm^3.

Record all your results in a table. You should include the volume of **FA 1**, the volume of distilled water, the reaction time and the reaction rate for each of your five experiments.

The rate of reaction can be calculated using the following formula.

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

Results

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) On the grid, plot the rate (y-axis) against the volume of **FA 1** (x-axis).
Start each axis at the origin (0,0).

Ring any anomalous points. Draw a line of best fit.

I	
II	
III	
IV	

[4]

(c) In these experiments, the volume of **FA 1** is a measure of the concentration of thiosulfate ions.

A student suggested that the graph shows that the rate of reaction is directly proportional to the concentration of thiosulfate ions.

Explain, using your graph, whether you agree with this student.

....

....

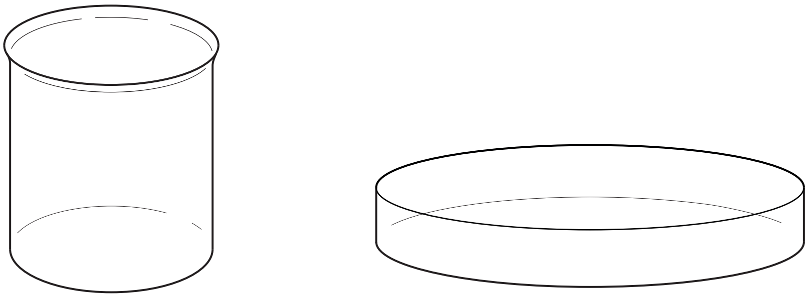
.... [1]

(d) Use your graph to calculate the time you would expect to record if you had used 12.50 cm^3 of **FA 1** and followed the same method.

Show clearly on the graph how you calculated this time.

time = ... s [2]

(e) Another student broke the beaker and decided to use a Petri dish instead.



beaker   Petri dish

Fig. 1.1

What effect, if any, would this have on the times measured in the experiment in **(a)**?
Explain your answer.

....

....

.... [2]

[Total: 17]

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2 Many salts contain water of crystallisation which can be removed by heating to form the anhydrous salt. You will determine the enthalpy change of dehydration for hydrated magnesium sulfate.

$$MgSO_4•7H_2O(s) \rightarrow MgSO_4(s) + H_2O(l)$$

You will determine this enthalpy change by measuring the changes in temperature when samples of hydrated magnesium sulfate and anhydrous magnesium sulfate are dissolved separately in excess water.

FA 3 is hydrated magnesium sulfate, $MgSO_4•7H_2O$.
FA 4 is anhydrous magnesium sulfate, $MgSO_4$.

(a) Method

Experiment 1

- Weigh the container with **FA 3**. Record the mass in the space below.
- Support the cup in the 250 cm^3 beaker.
- Rinse the 25 cm^3 measuring cylinder with distilled water. Use the 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.
- Tip all of the **FA 3** into the water in the cup. Stir the mixture thoroughly.
- Record the highest or lowest temperature of the mixture.
- Calculate the change in temperature. Record this change.
- Weigh the container with any remaining **FA 3**. Record the mass.
- Calculate the mass of **FA 3** used. Record this mass.

Experiment 2

- Repeat the method using **FA 4** in place of **FA 3**. Use the second cup.

Results

I	
II	
III	
IV	
V	

[5]

(b) Calculations

(i) Calculate the heat energy transferred, in J, in each experiment.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.

Experiment 1 with FA 3	**Experiment 2 with FA 4**
heat energy = ... J	heat energy = ... J

[1]

(ii) Calculate the enthalpy change, ΔH, in $kJ\,mol^{-1}$, when 1.0 mol of solid dissolves in water in each experiment.

Experiment 1 with FA 3	**Experiment 2 with FA 4**
ΔH_1 = ... $kJ\,mol^{-1}$ *sign* *value*	ΔH_2 = ... $kJ\,mol^{-1}$ *sign* *value*

[3]

(iii) Use your answers to **(b)(ii)** to calculate the enthalpy change when 1.0 mol of hydrated magnesium sulfate is dehydrated to form 1.0 mol of anhydrous magnesium sulfate.

$$MgSO_4{\bullet}7H_2O(s) \rightarrow MgSO_4(s) + 7H_2O(l)$$

Show clearly, by a Hess's energy cycle or any other suitable means, how you calculated your answer.

If you were unable to complete the calculation in **(b)(ii)** then assume that the enthalpy change in Experiment 1, ΔH_1, is +8.7 kJ mol^{-1} and that the enthalpy change in Experiment 2, ΔH_2, is –15.5 kJ mol^{-1}. These may **not** be the correct values.

enthalpy change of dehydration of $MgSO_4{\bullet}7H_2O$ = ... kJ mol^{-1} [2]
sign *value*

[Total: 11]

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)** **(i)** A student finds a container of a compound which is thought to be **FA 3**. The student labels the container **FA 5**.

Carry out tests to determine whether your sample of **FA 5** contains magnesium ions, sulfate ions and water of crystallisation.
Record your tests and observations in a suitable form in the space below.

If any solid is heated, a hard-glass test-tube must be used.

[4]

(ii) Complete Table 3.1 to indicate the contents of **FA 5**.
Put a tick (✓) in **one** box in each row.

Table 3.1

	yes	no
FA 5 contains magnesium ions		
FA 5 contains sulfate ions		
FA 5 contains water of crystallisation		

[1]

(b) **FA 6** contains one cation and one anion, both of which are listed in the Qualitative analysis notes.

(i) In a hard-glass test-tube heat a spatula measure of **FA 6**. Heat gently at first and then heat strongly. Record **all** your observations.

....

....

....

....

.... [2]

(ii) Carry out the following tests and record your observations.

Table 3.2

test	*observations*
Test 1 To a small spatula measure of **FA 6** in a test-tube, add 5 cm depth of dilute hydrochloric acid. **Keep the solution for Test 2.**	
Test 2 Put 1 cm depth of the solution from Test 1 in a test-tube. Add aqueous ammonia dropwise at first and then until it is in excess.	

[2]

(iii) Use your observations from **(b)(i)** and **(ii)** to identify the ions present in **FA 6**.

cation .... anion .... [1]

(iv) Write the **ionic** equation for the reaction that occurs in Test 2 before excess ammonia is added. Include state symbols.

If you were unable to identify the cation in the solution then use the symbol M^{2+}.

.... [2]

[Total: 12]

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 A*l* aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 C*l* 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 T*l* 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 F*l* 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 –