Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME											
CENTRE NUMBER							CANDIDATE NUMBER				

3994171993

CHEMISTRY **9701/34**

Paper 3 Advanced Practical Skills 2 **October/November 2023**

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	

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

1 Iron(III) ions, Fe^{3+}, can oxidise iodide ions, I^-, to iodine, I_2.

$$2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$$

It is possible to determine the rate of this reaction by measuring the time to produce a certain amount of iodine. To do this, thiosulfate ions, $S_2O_3^{2-}$, are added to the reaction mixture. The thiosulfate ions react immediately with the iodine produced by the reaction and convert it back to iodide ions.

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

Iodine remains in the solution when all the thiosulfate ions have reacted. The remaining iodine is detected by starch indicator in the reaction mixture, which causes the solution to turn blue-black.

In this experiment you will investigate how the rate of the reaction between iron(III) ions and iodide ions is affected by the concentration of the iron(III) ions.

FB 1 is 0.0500 mol dm^{-3} acidified iron(III) chloride, $FeCl_3$.
FB 2 is 0.0500 mol dm^{-3} potassium iodide, KI.
FB 3 is 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FB 4 is starch indicator.

(a) Method

Experiment 1

- Fill the burette labelled **FB 1** with **FB 1**.
- Run 20.00 cm^3 of **FB 1** into a 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to add the following to the **other** 100 cm^3 beaker:
  - 10.0 cm^3 of **FB 2**
  - 20.0 cm^3 of **FB 3**
  - 10.0 cm^3 of **FB 4**.
- Add the contents of the first beaker to the second beaker and start timing **immediately**. Ignore any initial colouration on mixing.
- Stir the mixture once and place the beaker on the white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Rinse both beakers and shake dry.
- Rinse and dry the glass rod.

Experiment 2

- Fill the other burette with distilled water.
- Run 10.00 cm^3 of **FB 1** into a 100 cm^3 beaker.
- Run 10.00 cm^3 of distilled water into the same beaker containing **FB 1**.
- Use the 25 cm^3 measuring cylinder to add the following to the **other** 100 cm^3 beaker:
  - 10.0 cm^3 of **FB 2**
  - 20.0 cm^3 of **FB 3**
  - 10.0 cm^3 of **FB 4**.
- Add the contents of the first beaker to the second beaker and start timing **immediately**. Ignore any initial colouration on mixing.
- Stir the mixture once and place the beaker on a white tile.
- Stop timing as soon as the solution turns blue-black.
- Record this reaction time to the nearest second.
- Rinse both beakers and shake dry.
- Rinse and dry the glass rod.

Experiments 3 to 5

- Carry out three further experiments to investigate how the reaction time changes with different volumes of **FB 1**.

The combined volume of **FB 1** and distilled water must always be 20.00 cm^3.
Do **not** use a volume of **FB 1** that is less than 5.00 cm^3.

The rate of reaction is given by the following expression.

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

Use this expression to calculate the rate for each of your experiments.

Record all your results in a single table. You should include the volume of **FB 1**, the volume of distilled water, the reaction time and the rate of reaction.

Results

I	
II	
III	
IV	
V	
VI	
VII	
VIII	
IX	

[9]

(b) On the grid opposite, plot the rate (on the *y*-axis) against the volume of **FB 1** (on the *x*-axis). Include the origin in your plot. Label any points that you consider to be anomalous. Draw the line of best fit.

I	
II	
III	
IV	

[4]

(c) In these experiments, the volume of **FB 1** is directly related to the concentration of iron(III) ions.
Using your graph, state what conclusion can be drawn about the relationship between the rate of reaction and the concentration of the iron(III) ions.

....

.... [1]

(d) A student wants to increase the concentration of the sodium thiosulfate solution while keeping the rest of the experiment the same. The student realises that the amount of thiosulfate ions must not be too high otherwise there will be no remaining iodine.

You will calculate the concentration of thiosulfate ions that will react with all the iodine produced in **Experiment 1**.

(i) Calculate the amount, in mol, of iron(III) ions in the solution at the start of **Experiment 1**.

amount of Fe^{3+} = ... mol [1]

(ii) Calculate the amount, in mol, of iodide ions in the solution at the start of **Experiment 1**.

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

(iii) Use the equation to determine the maximum amount, in mol, of iodine that can be made during this reaction.

$$2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$$

amount of I_2 = ... mol [1]

(iv) Use the equation to determine the concentration, in $mol\,dm^{-3}$, of sodium thiosulfate solution that will react with all the iodine produced in **Experiment 1**.
Show your working.

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

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

[Total: 19]

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2 In this experiment you will determine the relative formula mass of an unknown ion, $\mathbf{A}^{2-}$. The ion is present in a salt with the formula $Na_2\mathbf{A}{\bullet}5H_2O$.

You will first determine the enthalpy change of solution, ΔH_{sol}, for $Na_2\mathbf{A}{\bullet}5H_2O$. To do this you will measure the temperature change when a known mass of the salt dissolves in a known volume of water. You will then use a literature value for the enthalpy change of solution to calculate the relative formula mass of $\mathbf{A}^{2-}$.

FB 5 is the salt, $Na_2\mathbf{A}{\bullet}5H_2O$.

(a) Method

- Support the cup in the 250 cm^3 beaker.
- Rinse the 25 cm^3 measuring cylinder with distilled water.
- Use the 25 cm^3 measuring cylinder to transfer 20.0 cm^3 of distilled water into the cup.
- Weigh the stoppered container with the **FB 5**. Record the mass.
- Measure and record the initial temperature of the water in the cup. You may need to tilt the cup to make sure that the bulb of the thermometer is covered.
- Carefully add all the sample of **FB 5** to the water in the cup.
- Stir the mixture and record the minimum temperature that is reached.
- Weigh the stoppered container and any residual **FB 5**. Record the mass.
- Calculate and record the mass of **FB 5** added to the water and the change in temperature.

I	
II	
III	
IV	

[4]

(b) Calculations

(i) Calculate the energy change in the reaction.

energy change = ... J [1]

(ii) A literature value for the enthalpy change of solution, ΔH_{sol}, for Na_2**A**$\bullet 5H_2O$ is $+47.4\,kJ\,mol^{-1}$.
Calculate the amount, in mol, of Na_2**A**$\bullet 5H_2O$ in your sample of **FB 5**.
Assume that the literature value was measured under the same conditions as your experiment.

amount of Na_2**A**$\bullet 5H_2O$ = ... mol [1]

(iii) Calculate the relative formula mass of **A**$^{2-}$.

relative formula mass of **A**$^{2-}$ = ... [1]

(c) A student suggests that the experiment can be made more accurate by increasing the volume of water used.

State whether the student is correct. Explain your answer.

....

.... [1]

[Total: 8]

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 **FB 6** is a salt which contains a cation and an anion from those listed in the Qualitative analysis notes.

FB 7 is a mixture of two acids. The possible acids are hydrochloric acid, nitric acid and sulfuric acid.

By carrying out the following tests you will identify the ions in **FB 6** and determine which acids are present in **FB 7**.

(a) Carry out the following tests and record your observations in Table 3.1.

Table 3.1

test	*observations*
Test 1 Place approximately one third of the sample of **FB 6** in a hard-glass test-tube and heat strongly, then	
leave to cool.	
Test 2 To an approximately 2 cm depth of **FB 7** in a boiling tube add carefully the remaining sample of **FB 6**. **Keep this solution for use in 3(b).**	

[4]

(b) **(i)** Choose reagents and carry out tests to identify the cation in **FB 6**.
Record your tests and observations.

[2]

(ii) State the formulae of the ions present in **FB 6**.

FB 6 contains .... and .... [1]

(c) **(i)** Choose reagents and carry out tests to identify which of the following acids are present in **FB 7**. Use a 1 cm^3 depth of **FB 7** for each test.
Record your observations.

test for hydrochloric acid ....

observations ....

....

test for nitric acid ....

observations ....

....

test for sulfuric acid ....

observations ....

....
[4]

(ii) State the formulae of the acids present in **FB 7**.

FB 7 contains .... and .... [1]

(iii) Give an ionic equation for any of the reactions you observed in **(c)(i)**. Include state symbols.

.... [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	$V_m = 22.4\,dm^3\,mol^{-1}$ 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 –