Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

9648606442

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **February/March 2023**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

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 30.
- 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.

This document has **12** pages. Any blank pages are indicated.

DC (LK/FC) 308777/3

1 Aqueous iron(II) ions, $Fe^{2+}(aq)$, are usually kept in acidic conditions to prevent them readily oxidising to aqueous iron(III) ions, $Fe^{3+}(aq)$.

$Fe^{2+}(aq)$ ions react with $Ag^{+}(aq)$ ions in a redox reaction. The following equilibrium is established.

$$Fe^{2+}(aq) + Ag^{+}(aq) \rightleftharpoons Fe^{3+}(aq) + Ag(s)$$

The concentration of $Fe^{2+}(aq)$ at equilibrium can be found by titration with a standard solution of aqueous potassium manganate(VII), $KMnO_4(aq)$. $KMnO_4(aq)$ is deep purple in colour. The equilibrium constant for the reaction can be found using the following equation.

$$K_c = \frac{[Fe^{3+}(aq)]_{eqm}}{[Fe^{2+}(aq)]_{eqm} \times [Ag^{+}(aq)]_{eqm}}$$

A student carries out the experiment using the following instructions.

step 1 Add 100.0 cm^3 of 0.200 mol dm^{-3} $AgNO_3(aq)$ to 100.0 cm^3 of 0.200 mol dm^{-3} $Fe(NO_3)_2(aq)$ in a 500 cm^3 conical flask and stopper the flask. Label the conical flask **A**.

step 2 Leave conical flask **A** for four hours, shaking intermittently. Then leave conical flask **A** untouched for one hour.

step 3 Use a pipette to transfer 25.00 cm^3 of the solution from conical flask **A** into a clean 250 cm^3 conical flask. Label this conical flask **B**.

step 4 Add 5 cm^3 of 1.00 mol dm^{-3} $NaCl(aq)$ to the solution in conical flask **B**. A white precipitate of silver chloride forms.

step 5 Use a measuring cylinder to add 20 cm^3 of 1.00 mol dm^{-3} sulfuric acid to conical flask **B**.

step 6 Rinse a burette and fill it with a standard solution of $KMnO_4(aq)$.

step 7 Add $KMnO_4(aq)$ to the mixture in conical flask **B** until an end-point is reached.

step 8 Empty conical flask **B** and rinse it with distilled water ready for the next titration.

The student repeats the titration until concordant readings are achieved.

(a) The student records their results in Table 1.1.

Table 1.1

	rough	titration 1	titration 2	titration 3
final burette reading / cm^3	10.60	20.35	30.25	9.85
initial burette reading / cm^3	0.10	10.70	20.35	0.10
titre / cm^3				

(i) Complete Table 1.1. [1]

(ii) Calculate a suitable mean titre to be used in the student's calculations.

Show clearly how you obtain the mean titre.

mean titre = ... cm^3 [1]

(b) State what is meant by a standard solution in **step 6**.

.... [1]

(c) **(i)** Suggest why conical flask **A** is left for four hours in **step 2**.

.... [1]

(ii) Suggest why conical flask **A** is **not** shaken during the final hour in **step 2**.

.... [1]

(d) Suggest why a measuring cylinder is the most appropriate apparatus to use for measuring sulfuric acid in **step 5**.

.... [1]

(e) State what the burette should be rinsed with in **step 6**.

.... [1]

(f) State the change of colour seen in the mixture in conical flask **B** at the end-point in **step 7**.

from .... to .... [1]

(g) The student repeats the experiment using $KMnO_4$(aq) at a lower concentration. The student obtains a larger mean titre.

Suggest one reason why a larger titre is better than a smaller titre.

.... [1]

(h) The equilibrium is shown.

$$Fe^{2+}(aq) + Ag^{+}(aq) \rightleftharpoons Fe^{3+}(aq) + Ag(s)$$

When another student carries out the titration with 0.0200 mol dm^{-3} $KMnO_4$(aq), the mean titre is 21.10 cm^3.

The ionic equation for the reaction between MnO_4^-(aq) and Fe^{2+}(aq) is shown.

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow 5Fe^{3+}(aq) + 4H_2O(l) + Mn^{2+}(aq)$$

(i) Calculate the concentration of Fe^{2+}(aq) in the equilibrium mixture.

$[Fe^{2+}(aq)]_{eqm}$ = ... mol dm^{-3} [2]

(ii) Suggest why it is **not** necessary to measure the concentration of Ag^+(aq) ions in the equilibrium mixture experimentally.

.... [1]

(iii) Determine the decrease in concentration of Fe^{2+}(aq) from the initial solution. Hence, determine the concentration of Fe^{3+}(aq) in the equilibrium mixture.

If you were unable to obtain an answer to **(h)(i)**, use $[Fe^{2+}(aq)]_{eqm}$ = 0.0804 mol dm^{-3}. This is **not** the correct answer.

$[Fe^{3+}(aq)]_{eqm}$ = ... mol dm^{-3} [1]

(iv) Determine the value of K_c. Include units in your answer.

K_c = ...

units = ...
[2]

[Total: 15]

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2 The reaction between iodide ions, $I^-(aq)$, and aqueous hydrogen peroxide, $H_2O_2(aq)$, takes place in acidic conditions.

reaction 1 $$2I^-(aq) + H_2O_2(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

A student carries out a series of experiments to investigate the order of reaction with respect to the concentration of $I^-(aq)$ ions. The student does this by measuring the time taken for a fixed amount of iodine to form.

A known amount of aqueous thiosulfate ions, $S_2O_3^{2-}(aq)$, in the reaction mixture react with $I_2(aq)$ formed in reaction 1.

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

After all of the $S_2O_3^{2-}(aq)$ ions have reacted in reaction 2, any further $I_2(aq)$ formed is detected using starch indicator.

The following materials are used:

- 50 cm^3 beaker containing the correct mass of solid potassium iodide crystals needed to make 250.0 cm^3 of 0.100 mol dm^{-3} KI(aq)
- 0.100 mol dm^{-3} $Na_2S_2O_3(aq)$
- 0.100 mol dm^{-3} $H_2O_2(aq)$
- 0.200 mol dm^{-3} $H_2SO_4(aq)$
- starch indicator
- distilled water.

(a) A second student looked at the equation for reaction 1 and stated the order with respect to the concentration of $I^-(aq)$ ions must be second order because the balanced equation contains $2I^-(aq)$.

Suggest why a balanced equation alone cannot be used to determine the order of a reaction.

.... [1]

(b) Describe how the student makes 250.0 cm^3 of 0.100 mol dm^{-3} KI(aq) starting from the sample of solid potassium iodide in the 50 cm^3 beaker.

Give the name and size of any key apparatus used. Describe how the student ensures the volume is exactly 250.0 cm^3.

You may wish to write your answer using a series of numbered steps.

....

....

....

....

....

.... [3]

(c) The student carries out Experiment 1 using the following steps.

step 1 Add 25 cm^3 of 0.200 mol dm^{-3} H_2SO_4(aq) to a conical flask.

step 2 Add 20.00 cm^3 of distilled water to the conical flask from a burette.

step 3 Add 5.00 cm^3 of 0.100 mol dm^{-3} KI(aq) to the conical flask from a burette.

step 4 Add 5.00 cm^3 of 0.100 mol dm^{-3} $Na_2S_2O_3$(aq) to the conical flask from a burette.

step 5 Add 2 cm^3 of starch indicator to the conical flask.

step 6 Use a burette to add 10.00 cm^3 of 0.100 mol dm^{-3} H_2O_2(aq) to a small beaker.

step 7 Add the contents of the beaker to the conical flask and start a timer immediately. Stop the timer when the starch indicates the presence of I_2(aq).

The student carries out a further six experiments by repeating **steps 1** to **7**, using the volumes shown in Table 2.1.

Table 2.1

experiment	volume of H_2SO_4(aq) / cm^3	volume of distilled water / cm^3	volume of KI(aq), *V* / cm^3	volume of $Na_2S_2O_3$(aq) / cm^3	volume of indicator / cm^3	time taken for colour change, *t* / s
1	25	20.00	5.00	5.00	2	257
2	25	17.50	7.50	5.00	2	120
3	25	15.00	10.00	5.00	2	112
4	25	12.50	12.50	5.00	2	76
5	25	10.00	15.00	5.00	2	1
6	25	5.00	20.00	5.00	2	59
7	25	0.00	25.00	5.00	2	44

(i) State how the student could improve the reliability of the experiment.

.... [1]

(ii) State the independent variable in Experiments 1 to 7.

.... [1]

(iii) In Experiment 5, the starch indicator changed colour immediately on adding H_2O_2(aq). The student realised an error had been made.

Suggest which step was missed in Experiment 5.

.... [1]

[Turn over

(d) The rate equation is represented as rate = $k[\text{I}^-]^n$.

- $[\text{I}^-]$ is proportional to the volume of KI(aq)
- n is the order of reaction with respect to I^-
- rate is proportional to $1/t$
- $\log(\text{rate}) = \log k + n\log[\text{I}^-]$

(i) Use the results from the student's experiments in **(c)** to complete Table 2.2.

V is the volume of KI(aq) and *t* is the time taken for the colour to change.

Give all values to **three** significant figures.

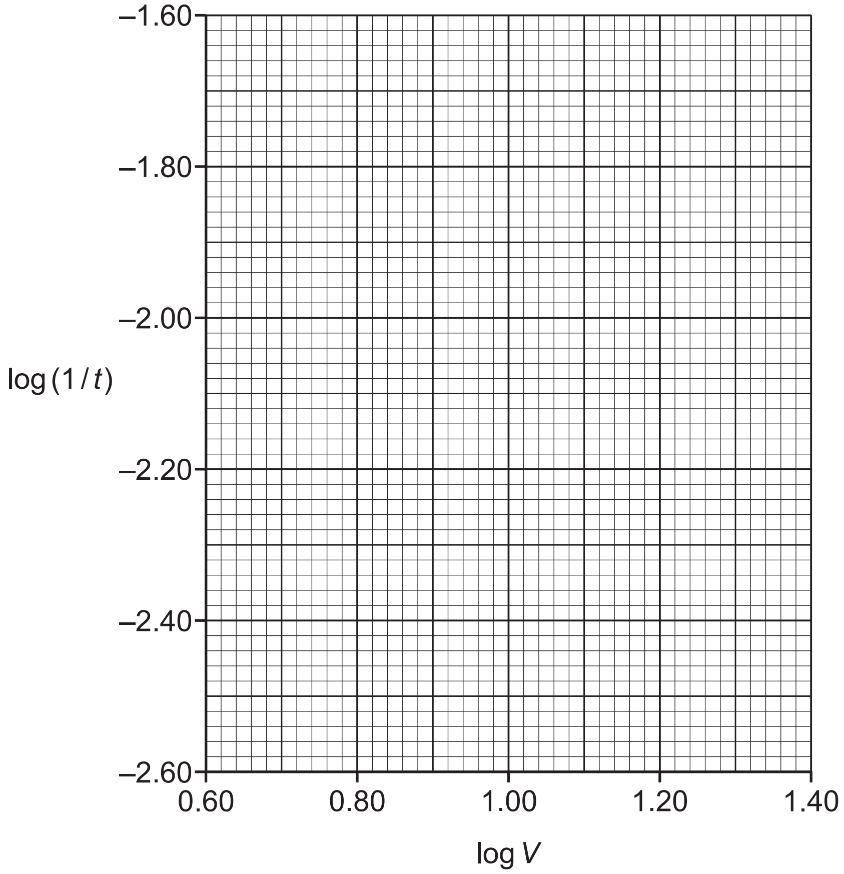
The results for Experiment 5 should **not** be used.

Table 2.2

experiment	V/cm^3	t/s	$\log V$	$\log(1/t)$
1	5.00	257		
2	10.00	120		
3	12.50	112		
4	15.00	76		
5	17.50	1	X	X
6	20.00	56		
7	25.00	44		

[2]

(ii) Plot a graph on the grid to show the relationship between log V and log (1 / t). Use a cross (x) to plot each data point. Draw a line of best fit.



[2]

(iii) A timing error caused the most anomalous point on the graph.

Circle this point and explain the error in timing which led to this point.

.... [1]

(iv) Use your graph to determine the gradient of the line of best fit.

State the coordinates of both points you used in your calculation. These must be selected from your line of best fit.

Give the gradient to **two** decimal places.

coordinates 1 .... coordinates 2 ....

gradient = ... [2]

(v) The total percentage error from measurements is determined to be 5.25%.

The true order of reaction is 1. Use this and your gradient from **(d)(iv)** to determine whether the error in the experiment could be accounted for by error from measurements or is caused by other factors.

Show any working.

....

.... [1]

[Total: 15]

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 –