

Cambridge International AS & A Level

**CANDIDATE
NAME**

CENTRE
NUMBER

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NUMBER**

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CHEMISTRY

9701/51

Paper 5 Planning, Analysis and Evaluation

May/June 2024

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.

1 Titration can be used to determine the concentration of dissolved oxygen in samples of river water.

The procedure for the experiment is given.

step 1 Use five 50 cm^3 graduated syringes, **A**, **B**, **C**, **D** and **E**, to collect five separate 30.0 cm^3 samples of river water.

step 2 In the laboratory, carefully add 5.0 cm^3 of 0.220 mol dm^{-3} manganese(II) sulfate, $\text{MnSO}_4\text{(aq)}$, into syringe **A** and mix well.

step 3 Add 5.0 cm^3 of alkaline aqueous potassium iodide into syringe **A** and mix well.

step 4 Add 10.0 cm^3 of dilute sulfuric acid into syringe **A** and mix well.

step 5 Transfer the contents of syringe **A** into a 150 cm^3 conical flask. Rinse syringe **A** using 10 cm^3 of distilled water and add washings to the conical flask.

step 6 Carry out **one** accurate titration of all the contents in the conical flask with $0.00200\text{ mol dm}^{-3}$ aqueous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3\text{(aq)}$, using starch indicator.

Repeat steps 2–6 for the samples in syringes **B–E**.

(a) Aqueous sodium thiosulfate can be prepared from $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O(s)}$.

(i) Determine the mass, in g, of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O(s)}$ required to prepare 500.0 cm^3 of $0.00200\text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3\text{(aq)}$.

$$\text{mass of } \text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O(s)} = \dots \text{ g} \quad [1]$$

(ii) Identify the piece of apparatus that should be used to prepare 500.0 cm^3 of $0.00200\text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3\text{(aq)}$ after the required mass of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O(s)}$ has been weighed out.

..... [1]

(b) The graduations on each syringe are every 1.0 cm^3 .

(i) Calculate the percentage error in the measurement of 5.0 cm^3 of alkaline aqueous potassium iodide by the syringe.

Show your working.

$$\text{percentage error} = \dots \quad [1]$$

(ii) Place **one** tick (✓) in each row in Table 1.1 to show the effect, if any, of using a larger volume of alkaline aqueous potassium iodide.

Table 1.1

	greater effect	no effect	smaller effect
uncertainty of the measurement			
percentage error of the measurement			

[1]

(c) The sample in the conical flask and the prepared solution of sodium thiosulfate are provided. Describe the following procedures for the experiment using syringe A.

(i) Preparing the clean burette before taking any readings.

.....

 [2]

(ii) Carrying out the **one** accurate titration in step 6.

.....

 [2]

(d) Suggest why the reaction mixture is mixed well in steps 2–4.

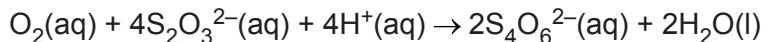
.....
 [1]

(e) Draw a table for recording the titration results for the five samples in syringes A–E.

[2]

[Turn over

(f) The overall reaction taking place in the experiment is shown.



A student carries out the experiment and determines the mean titre to be 12.65 cm^3 .

Calculate the concentration, in mol dm^{-3} , of dissolved oxygen in the river water.

concentration of dissolved oxygen = mol dm^{-3} [2]

(g) Freshly distilled water does **not** contain any dissolved oxygen.

A student decides to run the procedure on a sample of freshly distilled water and at the end obtains a value of $2.26 \times 10^{-5}\text{ mol dm}^{-3}$ dissolved oxygen.

(i) Suggest why the student did **not** get a value of 0 mol dm^{-3} . Assume the procedure was carried out correctly.

..... [1]

(ii) Suggest how the value of $2.26 \times 10^{-5}\text{ mol dm}^{-3}$ could be used to improve the answer in (f).

..... [1]

(h) Suggest why this method is unsuitable for samples of tap water that have been purified by chlorination and so contain $\text{Cl}_2(\text{aq})$.

..... [1]

[Total: 16]

2 The activation energy, E_A , for the reaction between dilute hydrochloric acid, $\text{HCl}(\text{aq})$, and aqueous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$, can be determined by an initial rates method.



The solid sulfur formed is seen as a white suspension in the reaction mixture. The reactants are mixed and the time, t , for a fixed quantity of sulfur to be formed is recorded.

A measure of the initial rate of the reaction is $\frac{1}{t}$.

Standard solutions of $0.100 \text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ and $0.500 \text{ mol dm}^{-3}$ $\text{HCl}(\text{aq})$ are supplied.

Measurements are taken for a series of temperatures using the following procedure.

step 1 A thermostatically controlled water bath is set up.

step 2 A 100 cm^3 conical flask is labelled **A** and a second 100 cm^3 conical flask is labelled **B**.

step 3 10.00 cm^3 of $0.100 \text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ is added to flask **A**. Flask **A** is placed in the water bath.

step 4 10 cm^3 of $0.500 \text{ mol dm}^{-3}$ $\text{HCl}(\text{aq})$ is added to flask **B**. Flask **B** is placed in the same water bath.

step 5 Wait for 10 minutes.

step 6 Flask **A** is removed from the water bath and placed on a tile marked with a black cross.

step 7 The contents of flask **B** are added to flask **A** and a timer started.

step 8 The timer is stopped when the black cross is no longer visible. The time is recorded.

(a) Suggest a reason why it is necessary to wait for 10 minutes in step 5.

..... [1]

(b) The procedure does not mention how a value for the temperature of the mixture during the reaction is obtained.

(i) State the temperature measurements that should be taken and at which stage in the procedure they should be taken.

..... [1]

(ii) State how to use the temperature measurements to determine an accurate value for the temperature of the mixture during the reaction.

..... [1]

(c) A student carries out the procedure at three different temperatures and records the measurements in Table 2.1.

Complete Table 2.1. Record values for temperature to the nearest whole number and the values for $\frac{1}{t}$ to **four** decimal places.

Table 2.1

temperature, $T/^\circ\text{C}$	time, t/s	temperature, T/K	$\frac{1}{t}/\text{s}^{-1}$
15	176		
24	92		
32	62		

[2]

(d) A second student carries out the procedure at six different temperatures and analyses their data to give the results in Table 2.2.

Table 2.2

$\frac{1}{T}/\text{K}^{-1}$	$\log\left(\frac{1}{t}\right)$
0.00353	-2.43
0.00336	-1.99
0.00325	-1.68
0.00314	-1.47
0.00302	-1.21
0.00287	-0.82

(i) Use the results from Table 2.2 to plot a graph on the grid in Fig. 2.1 to show the relationship between $\log\left(\frac{1}{t}\right)$ and $\frac{1}{T}$. Use a cross (x) to plot each data point. Draw a line of best fit.

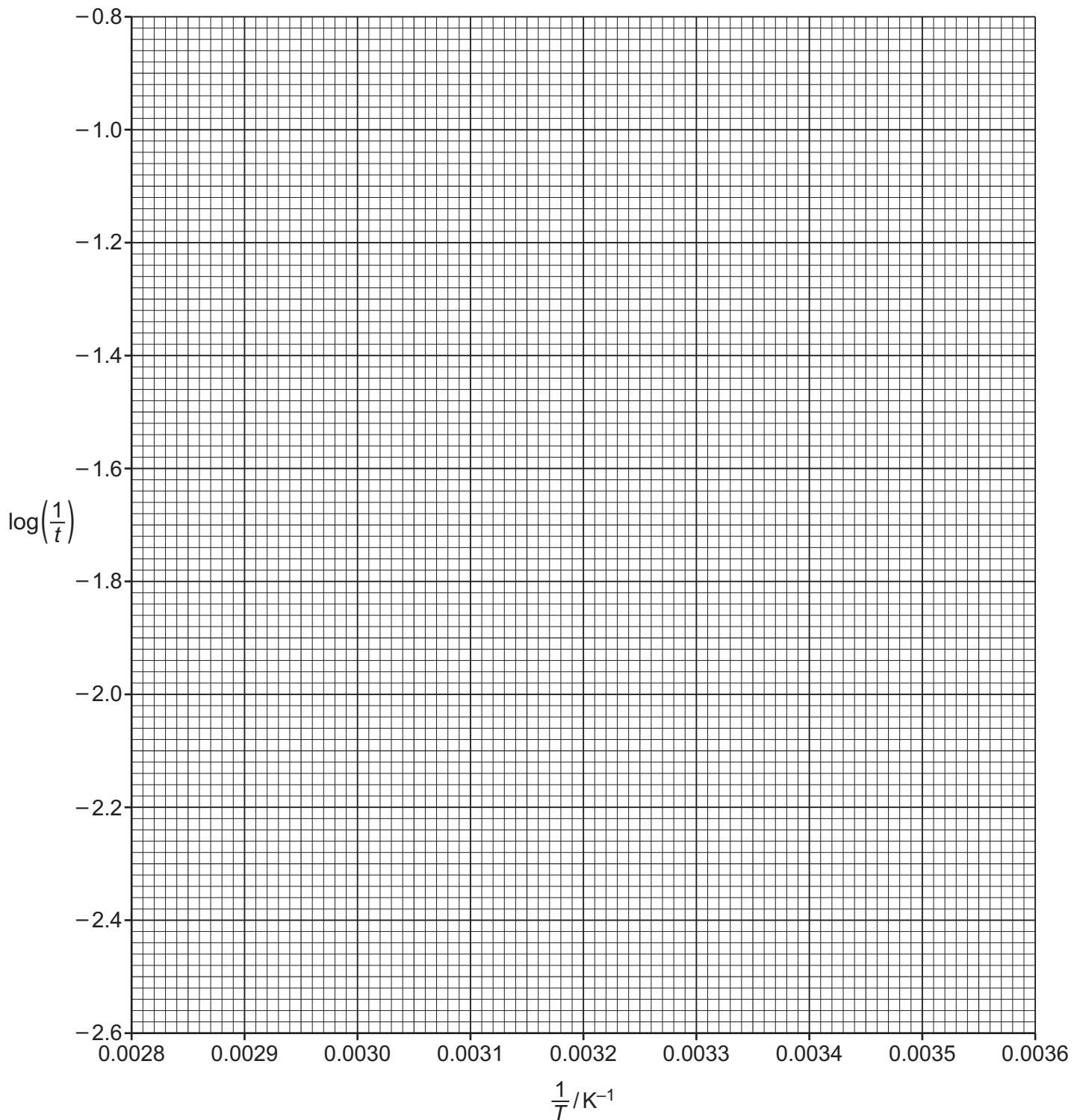


Fig. 2.1

[2]

(ii) Determine the gradient of your line of best fit in Fig. 2.1. State the coordinates of both points you use in your calculation. These must be selected from your line of best fit. Give the gradient to **three** significant figures.

coordinates 1 coordinates 2

gradient = K
[2]

(iii) An equation relating time and temperature variables is shown.

$$\log\left(\frac{1}{t}\right) = -\frac{0.434E_A}{RT} + \text{constant}$$

Determine the activation energy, E_A , of this reaction using this equation and your answer to (d)(ii).

(If you were unable to find the gradient in (d)(ii), then use the value -3.21×10^3 K. This is **not** the correct answer.)

Include units in your answer.

Show your working.

E_A =

units =
[3]

(iv) Use your graph to state whether the results from the experiment are reliable. Justify your answer.

.....
..... [1]

(e) Suggest a change to **one** controlled variable that the student could make so that the time measured for a given temperature is shorter.

.....
..... [1]

[Total: 14]

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

1		2		Group											
13		14		15		16		17		18					
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Li	Be														
lithium	beryllium														
6.9	9.0														
11	12	Mg													
		magnesium													
23.0	24.3														
19	20	Sc													
		scandium													
39.1	40.1														
K	Ca	Ti													
		titanium													
39.1	40.1														
37	38	Y													
		yttrium													
85.5	87.6	Zr													
		zirconium													
85.5	87.6														
55	56	Hf													
		hafnium													
132.9	137.3	Ba													
		barium													
132.9	137.3														
87	88	Rf													
		rutherfordium													
Key															
atomic number															
atomic symbol															
name															
relative atomic mass															
57	58	La													
		lanthanum													
138.9	140.1														
89	90	Th													
		thorium													
232.0	231.0														
lanthanoids															
60	61	Pm													
		neodymium													
144.2	140.9														
91	92	Pa													
		protactinium													
231.0	232.0														
actinoids															
5	6	B													
		boron													
10.8	12.0														
13	14	Si													
		silicon													
27.0	28.1														
5	6	C													
		carbon													
12.0	14.0														
13	14	Ge													
		germanium													
72.6	74.9														
13	14	As													
		arsenic													
79.0	79.9														
5	6	Br													
		bromine													
79.9	83.8														
13	14	Kr													
		krypton													
83.8	83.8														
13	14	Xe													
		xenon													
131.3	131.3														
5	6	At													
		astatine													
86	86	Rn													
		radon													
—	—														
69	70	Yb													
		ytterbium													
173.1	173.1														
71	71	Lu													
		lutetium													
175.0	175.0														
103	103	Lr													
		lawrencium													
—	—														
101	101	Md													
		mendeleyium													
—	—														
102	102	No													
		nobelium													
—	—														
117	117	Ts													
		thorium													
116	116	Lv													
		livermorium													
—	—														
118	118	Og													
		ogganesson													
—	—														