Cambridge Assessment
International Education

Cambridge International AS & A Level

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9789818768

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.

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

DC (DE/CT) 326103/3

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, $MnSO_4(aq)$, 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 mol dm^{-3} aqueous sodium thiosulfate, $Na_2S_2O_3(aq)$, using starch indicator.

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

(a) Aqueous sodium thiosulfate can be prepared from $Na_2S_2O_3{\bullet}5H_2O(s)$.

(i) Determine the mass, in g, of $Na_2S_2O_3{\bullet}5H_2O(s)$ required to prepare 500.0 cm^3 of 0.00200 mol dm^{-3} $Na_2S_2O_3(aq)$.

mass of $Na_2S_2O_3{\bullet}5H_2O(s)$ = ... g [1]

(ii) Identify the piece of apparatus that should be used to prepare 500.0 cm^3 of 0.00200 mol dm^{-3} $Na_2S_2O_3(aq)$ after the required mass of $Na_2S_2O_3{\bullet}5H_2O(s)$ 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.

percentage error = ... [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]

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

$$O_2(aq) + 4S_2O_3^{2-}(aq) + 4H^+(aq) \rightarrow 2S_4O_6^{2-}(aq) + 2H_2O(l)$$

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 2.26×10^{-5} 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 2.26×10^{-5} 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 Cl_2(aq).

....

.... [1]

[Total: 16]

2 The activation energy, E_A, for the reaction between dilute hydrochloric acid, HCl(aq), and aqueous sodium thiosulfate, $Na_2S_2O_3$(aq), can be determined by an initial rates method.

$$2HCl(aq) + Na_2S_2O_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + S(s) + SO_2(g)$$

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 mol dm^{-3} $Na_2S_2O_3$(aq) and 0.500 mol dm^{-3} HCl(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 mol dm^{-3} $Na_2S_2O_3$(aq) is added to flask **A**. Flask **A** is placed in the water bath.

step 4 10 cm^3 of 0.500 mol dm^{-3} HCl(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/°C	time, t/s	temperature, T/K	$\frac{1}{t}$/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

$\frac{1}{T}$/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 (×) to plot each data point. Draw a line of best fit.

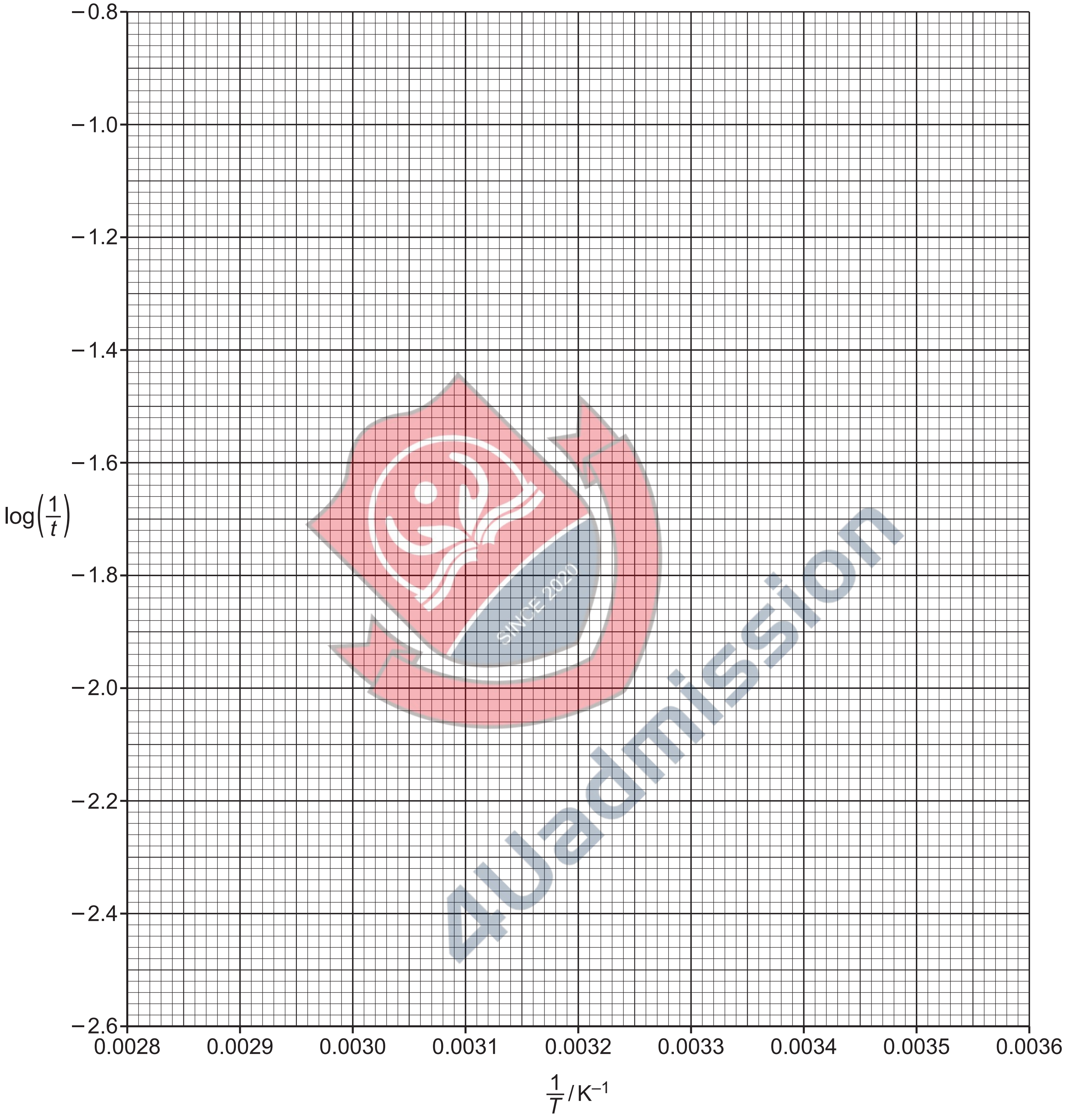

Fig. 2.1

[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]

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Important values, constants and standards

molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Faraday constant	$F = 9.65 \times 10^{4}\,\mathrm{C\,mol^{-1}}$
Avogadro constant	$L = 6.022 \times 10^{23}\,\mathrm{mol^{-1}}$
electronic charge	$e = -1.60 \times 10^{-19}\,\mathrm{C}$
molar volume of gas	$V_m = 22.4\,\mathrm{dm^3\,mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\mathrm{dm^3\,mol^{-1}}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\mathrm{mol^2\,dm^{-6}}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\mathrm{kJ\,kg^{-1}\,K^{-1}}$ ($4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$)

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 144.2	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 –