



CANDIDATE
NAME

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NUMBER

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CANDIDATE
NUMBER

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9701/51

October/November 2023

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

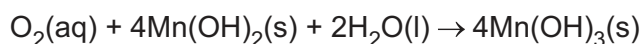
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- 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.

- 1 The concentration of dissolved oxygen in a sample of water can be measured using the following method.

Manganese(II) hydroxide, $\text{Mn}(\text{OH})_2$, is oxidised by the oxygen dissolved in a sample of water to form manganese(III) hydroxide, $\text{Mn}(\text{OH})_3$.

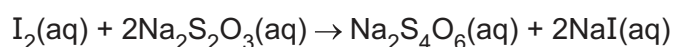


The manganese(III) hydroxide then reacts with iodide ions to produce aqueous iodine.



The amount of iodine produced is proportional to the amount of dissolved oxygen.

25.0 cm³ of the solution containing aqueous iodine is transferred into a conical flask and titrated against $1.00 \times 10^{-3} \text{ mol dm}^{-3}$ sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.



- (a) (i) Complete Table 1.1 and determine the mean titre to be used in calculating the concentration of dissolved oxygen.

Table 1.1

	trial run	run 1	run 2	run 3
final burette reading / cm ³	27.30	28.10	28.25	26.95
initial burette reading / cm ³	0.00	1.10	1.55	0.15
titre / cm ³				

mean titre = cm³ [2]

- (ii) Calculate the concentration of dissolved oxygen in the 25.0 cm³ of solution.
Show your working.

concentration of dissolved oxygen in 25.0 cm³ of solution = mol dm⁻³ [3]

- (b) Suggest a suitable piece of apparatus for the transfer of 25.0 cm^3 of the solution containing aqueous iodine.

..... [1]

- (c) Water samples are collected in full sealed flasks.

Explain why the sealed flask must be completely full.

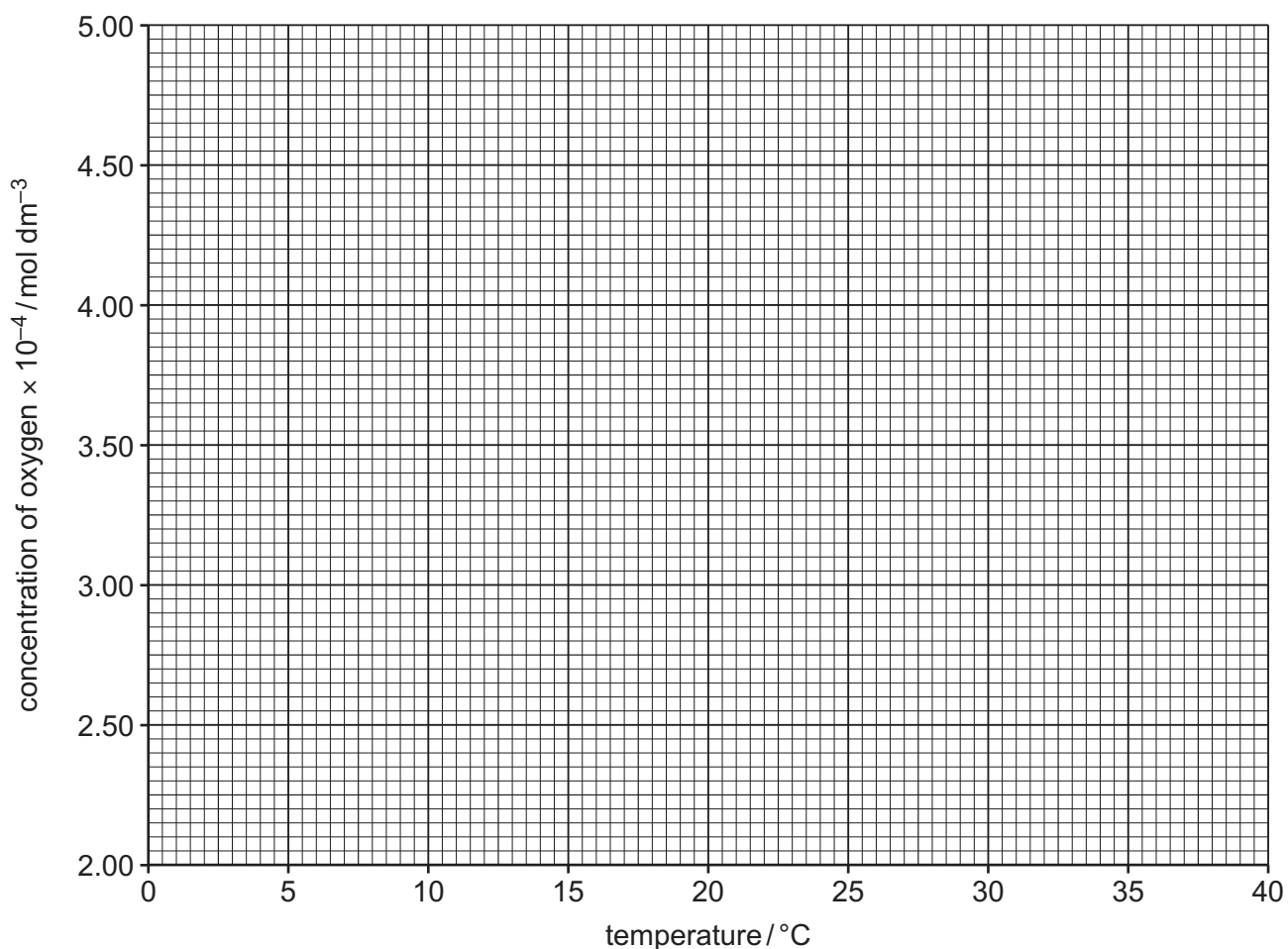
.....
..... [1]

- (d) The concentration of oxygen in water at different temperatures is shown in Table 1.2. The concentration value is missing for 25°C.

Table 1.2

temperature/°C	concentration of oxygen $\times 10^{-4}/\text{mol dm}^{-3}$
0	4.58
5	3.97
10	3.20
15	3.13
20	2.82
25	
30	2.33
35	2.15
40	2.05

- (i) Plot a graph of concentration of oxygen (y-axis) against temperature (x-axis) on the grid. Use a cross (×) to plot each data point. Draw a smooth curve of best fit.



[2]

- (ii) Use the graph to deduce the concentration of oxygen at 25 °C.

concentration of oxygen at 25 °C = mol dm⁻³ [1]

- (iii) Circle the most anomalous point on the graph.

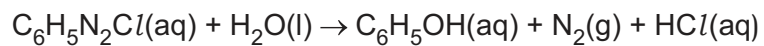
Suggest an explanation for this anomaly. Assume that there was no error in measuring oxygen concentration.

.....

 [2]

[Total: 12]

- 2 Benzenediazonium chloride, $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$, decomposes in water as shown in the following equation.



A solution of $0.0750 \text{ mol dm}^{-3}$ of $\text{C}_6\text{H}_5\text{N}_2\text{Cl}(\text{aq})$ decomposes at a constant temperature of 50°C . The volume of nitrogen gas, $\text{N}_2(\text{g})$, collected is recorded every 5 minutes for 45 minutes.

- (a) Draw a labelled diagram to show how the apparatus could be set up to carry out this experiment.

[3]

(b) Using this method, a student obtains the graph shown in Fig. 2.1.

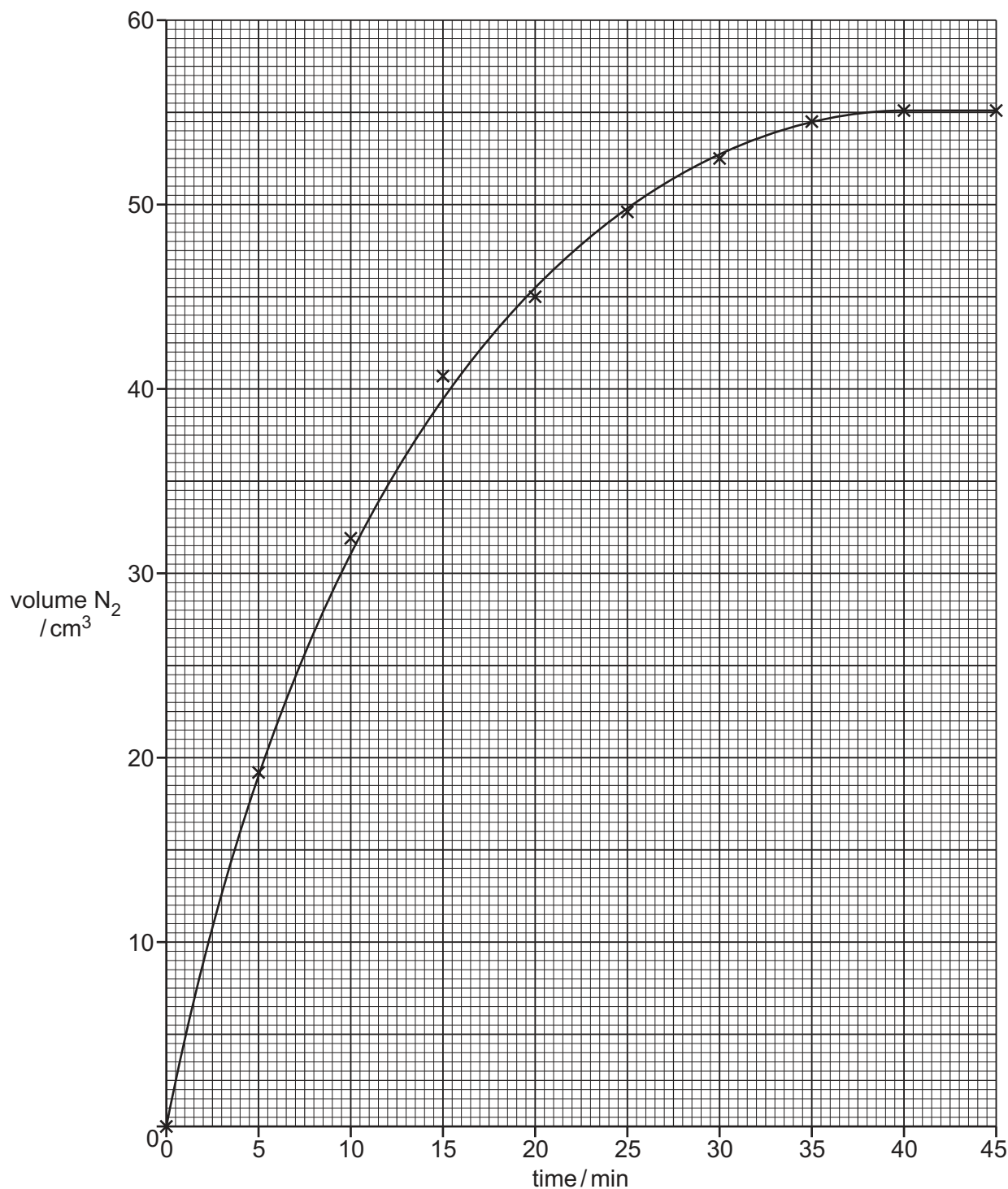


Fig. 2.1

- (i) On Fig. 2.1, draw a tangent to the curve at $t = 0$ mins. Calculate the initial rate of reaction in $\text{cm}^3 \text{min}^{-1}$.

initial rate of reaction = $\text{cm}^3 \text{min}^{-1}$ [2]

- (ii) Explain why the initial rate of reaction is calculated at $t = 0$ mins rather than dividing the total volume of gas produced by the time taken to produce it.

.....

 [1]

- (iii) Describe how the curve in Fig. 2.1 would be different, if at all, if the atmospheric pressure increases. All other conditions stay the same.

.....

 [1]

- (iv) On Fig. 2.1, draw a second curve to show the graph produced if the same volume of $0.0375 \text{ mol dm}^{-3}$ $\text{C}_6\text{H}_5\text{N}_2\text{Cl}(\text{aq})$ decomposes at a constant temperature of 50°C . All other conditions stay the same. [1]

- (c) Another student investigates the effect of changing the concentration of $\text{C}_6\text{H}_5\text{N}_2\text{Cl}(\text{aq})$ at 50°C . He measures the time taken to collect 0.0150 dm^3 of $\text{N}_2(\text{g})$ and calculates the rate of N_2 production by dividing 0.0150 dm^3 by the time taken. The results are shown in Table 2.1.

Table 2.1

concentration of $\text{C}_6\text{H}_5\text{N}_2\text{Cl}(\text{aq})$ / mol dm^{-3}	time taken to collect 0.0150 dm^3 of N_2/s	rate of N_2 production / $\text{dm}^3 \text{ s}^{-1}$
0.500	21	
0.400	33	
0.300	48	
0.200	64	
0.100	122	

- (i) Complete the table to calculate the values for the rate of N_2 production. Give your answers to **three** significant figures. [1]

- (ii) The reaction is first order and obeys the following rate equation.

$$\text{rate} = k [\text{C}_6\text{H}_5\text{N}_2\text{Cl}]$$

Explain how the data in Table 2.1 supports this statement.

.....
 [1]

- (iii) State the dependent variable in this investigation.

..... [1]

- (iv) The student wants to perform a similar experiment using $0.200 \text{ mol dm}^{-3} \text{ C}_6\text{H}_5\text{N}_2\text{Cl(aq)}$.

Describe how the student should make a standard solution of 100.0 cm^3 of $0.200 \text{ mol dm}^{-3} \text{ C}_6\text{H}_5\text{N}_2\text{Cl(aq)}$ starting from a solution of $0.500 \text{ mol dm}^{-3} \text{ C}_6\text{H}_5\text{N}_2\text{Cl(aq)}$.

Give the name and size of any key apparatus which should be used and describe how the student should ensure the volume is exactly 100.0 cm^3 .

Write your answer using a series of numbered steps.

.....

 [3]

- (v) Explain why (iv) must be carried out at a temperature below 5°C .

..... [1]

- (d) $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$ is used in the manufacture of synthetic dyes. A student prepares a sample of the dye using the reaction scheme shown in Fig. 2.2.

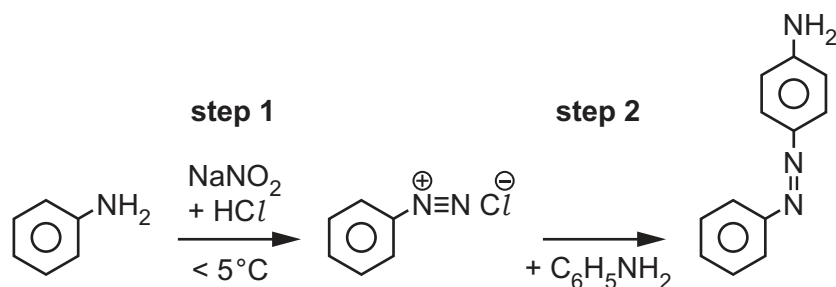


Fig. 2.2

In **step 1**, phenylamine, $\text{C}_6\text{H}_5\text{NH}_2$, is converted into $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$.

In **step 2**, $\text{C}_6\text{H}_5\text{N}_2\text{Cl}$ is reacted with more $\text{C}_6\text{H}_5\text{NH}_2$ to produce the solid dye, which is then filtered.

- (i) The student's final yield was 52%. They had not spilled any reagents or products. Suggest **two** reasons why the student's yield was lower than 100%. Assume no errors were made in the measurement of any substances.

reason 1:

.....

.....

reason 2:

.....

.....

[2]

- (ii) Explain why the solid dye should be dried before assessing the melting point.

.....

..... [1]

[Total: 18]

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

Group																			
1	2	13															16	17	18
		<div>1 H hydrogen 1.0</div>																	
		<div>2 He helium 4.0</div>																	
		<div>3 Li lithium 6.9</div>																	
		<div>4 Be beryllium 9.0</div>																	
		<div>5 B boron 10.8</div>																	
		<div>6 C carbon 12.0</div>																	
		<div>7 N nitrogen 14.0</div>																	
		<div>8 O oxygen 16.0</div>																	
		<div>9 F fluorine 19.0</div>																	
		<div>10 Ne neon 20.2</div>																	
		<div>11 Na sodium 23.0</div>																	
		<div>12 Mg magnesium 24.3</div>																	
		<div>13 Al aluminium 27.0</div>																	
		<div>14 Si silicon 28.1</div>																	
		<div>15 P phosphorus 31.0</div>																	
		<div>16 S sulfur 32.1</div>																	
		<div>17 Cl chlorine 35.5</div>																	
		<div>18 Ar argon 39.9</div>																	
		<div>19 K potassium 39.1</div>																	
		<div>20 Ca calcium 40.1</div>																	
		<div>21 Sc scandium 45.0</div>																	
		<div>22 Ti titanium 47.9</div>																	
		<div>23 V vanadium 50.9</div>																	
		<div>24 Cr chromium 52.0</div>																	
		<div>25 Mn manganese 54.9</div>																	
		<div>26 Fe iron 55.8</div>																	
		<div>27 Co cobalt 58.9</div>																	
		<div>28 Ni nickel 58.7</div>																	
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		<div>30 Zn zinc 65.4</div>																	
		<div>31 Ga gallium 69.7</div>																	
		<div>32 Ge germanium 72.6</div>																	
		<div>33 As arsenic 74.9</div>																	
		<div>34 Se selenium 79.0</div>																	
		<div>35 Br bromine 79.9</div>																	
		<div>36 Kr krypton 83.8</div>																	
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