



CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

9701/51

October/November 2023

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

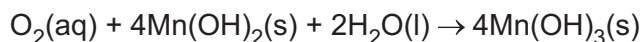
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction 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, Mn(OH)_2 , is oxidised by the oxygen dissolved in a sample of water to form manganese(III) hydroxide, Mn(OH)_3 .

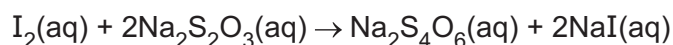


The manganese(III) hydroxide then reacts with iodide ions to produce aqueous iodine.



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.

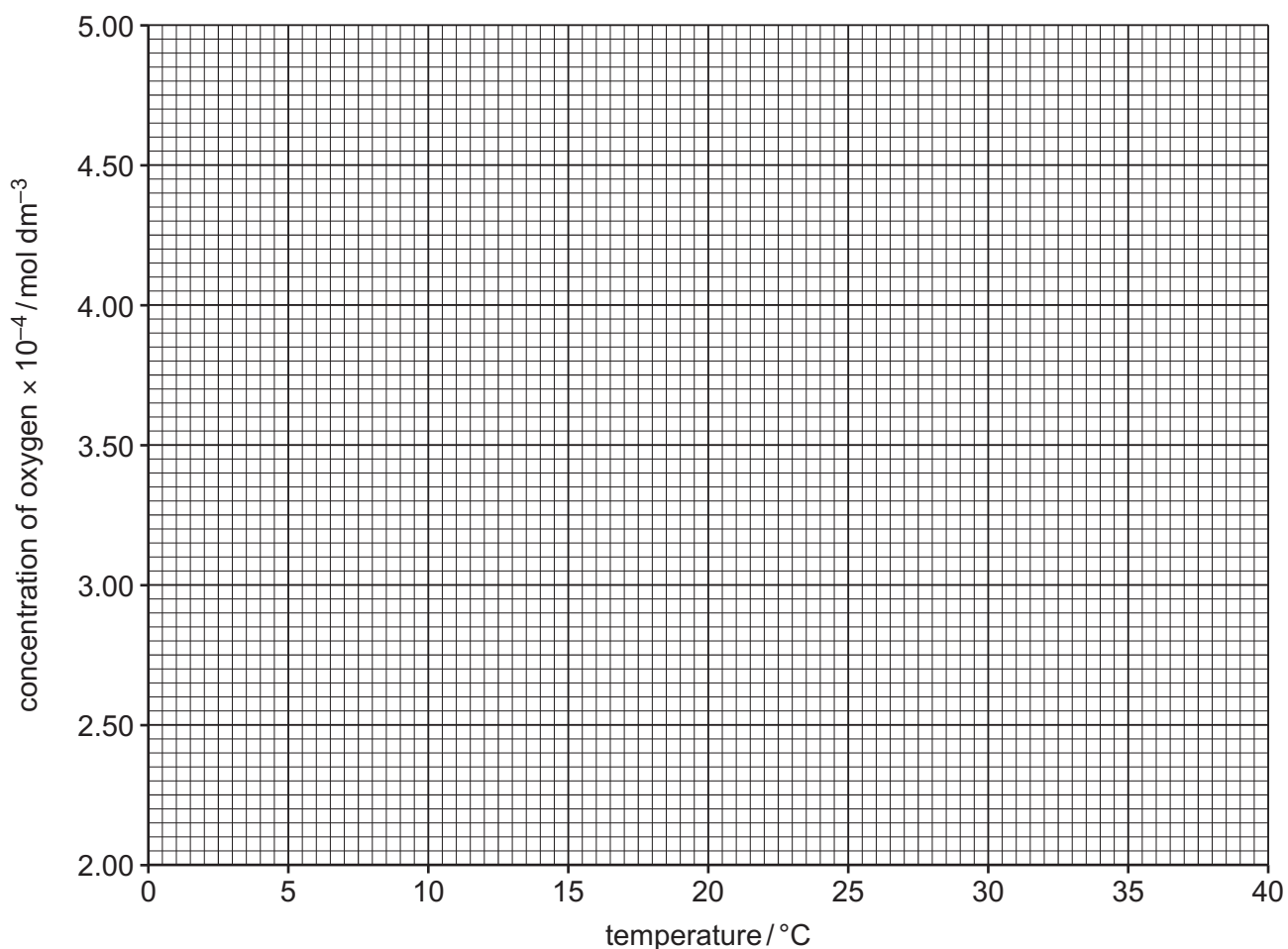
.....
..... [1]

- (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.

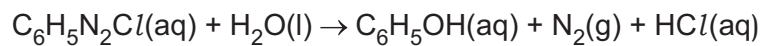
Suggest an explanation for this anomaly. Assume that there was no error in measuring oxygen concentration.

.....

 [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.

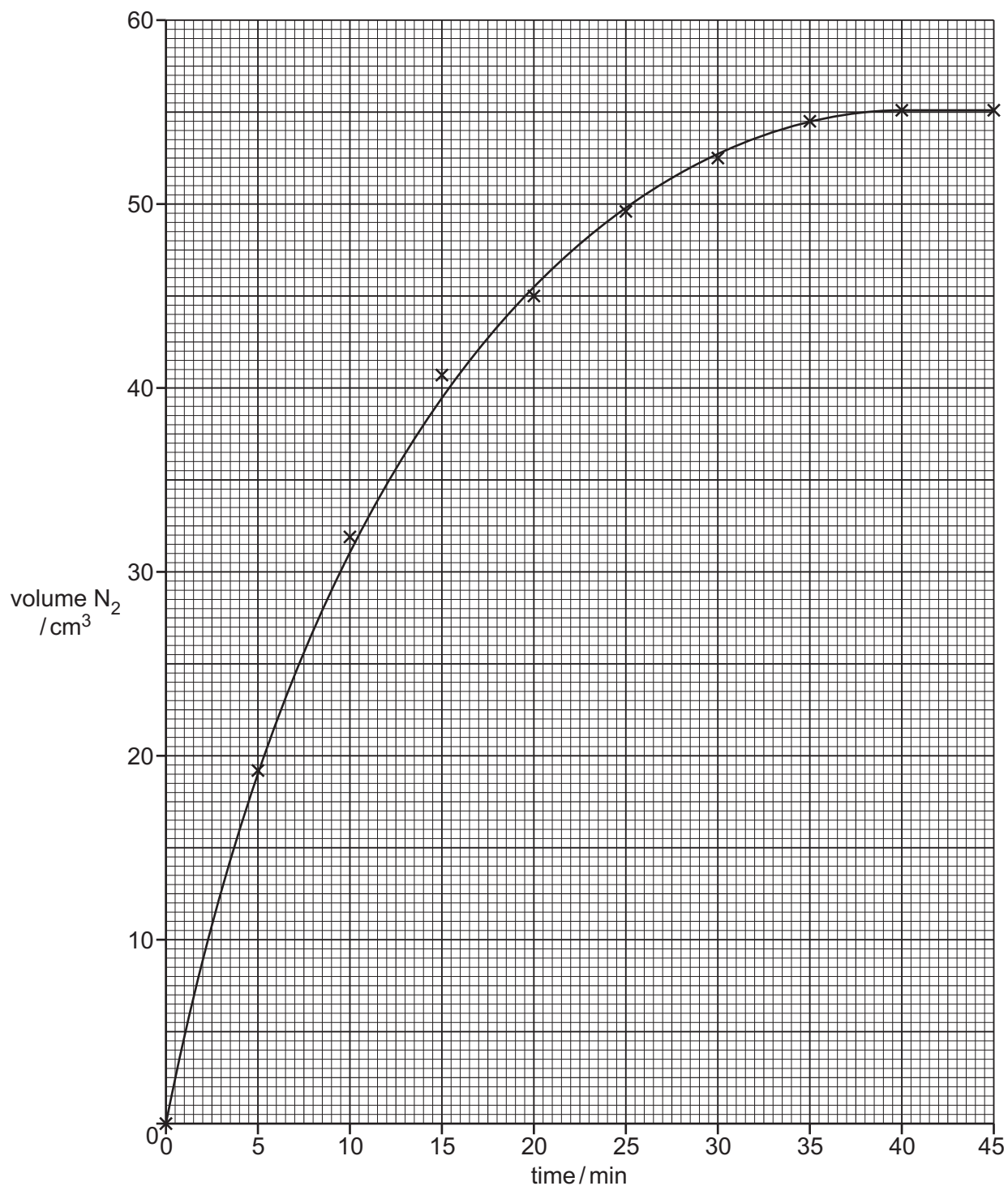


Fig. 2.1

- (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.



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.

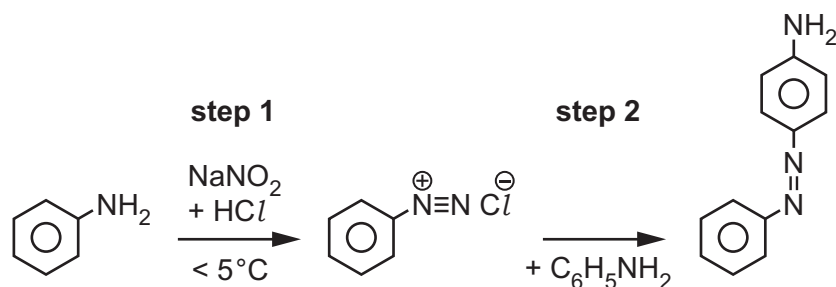


Fig. 2.2

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	1										13	14	15	16	17	18								
		Key																							
		1 H hydrogen 1.0																							
3	4	atomic number atomic symbol name relative atomic mass										5	6	7	8	9	10	11	12	13	14	15	16	17	18
Li lithium 6.9	Be beryllium 9.0											B boron 10.8	C carbon 12.0	N nitrogen 14.0	O oxygen 16.0	F fluorine 19.0	Ne neon 20.2								
Na sodium 23.0	Mg magnesium 24.3											Al aluminium 27.0	Si silicon 28.1	P phosphorus 31.0	S sulfur 32.1	Cl chlorine 35.5	Ar argon 39.9								
11	12											13	14	15	16	17	18								
Na	Mg											Al	Si	P	S	Cl	Ar								
19	20											31	32	33	34	35	36								
K	Ca											Ga	Ge	As	Se	Br	Kr								
potassium 39.1	calcium 40.1											gallium 69.7	germanium 72.6	arsenic 74.9	selenium 79.0	bromine 79.9	krypton 83.8								
37	38											49	50	51	52	53	54								
Rb	Sr											In	Sn	Sb	Te	I	Xe								
rubidium 85.5	strontium 87.6											indium 114.8	tin 118.7	antimony 121.8	tellurium 127.6	iodine 126.9	xenon 131.3								
55	56											81	82	83	84	85	86								
Cs	Ba											Tl	Pb	Bi	Po	At	Rn								
caesium 132.9	barium 137.3											thallium 204.4	lead 207.2	bismuth 209.0	polonium —	astatine —	radon —								
87	88											113	114	115	116	117	118								
Fr	Ra											Nh	Fl	Mc	Lv	Ts	Og								
francium —	radium —											nihonium —	flerovium —	moscovium —	livermorium —	tennessine —	ognesson —								

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	euporium	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
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	—

Lanthanoids

actinoids