Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/53**

Paper 5 Planning, Analysis and Evaluation **October/November 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.

[Turn over

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, $Mn(OH)_3$.

$$O_2(aq) + 4Mn(OH)_2(s) + 2H_2O(l) \rightarrow 4Mn(OH)_3(s)$$
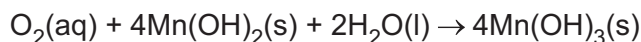
The manganese(III) hydroxide then reacts with iodide ions to produce aqueous iodine.

$$2Mn(OH)_3(s) + 6HCl(aq) + 2KI(aq) \rightarrow 2MnCl_2(aq) + 2KCl(aq) + I_2(aq) + 6H_2O(l)$$

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

$25.0\,cm^3$ of the solution containing aqueous iodine is transferred into a conical flask and titrated against $1.00 \times 10^{-3}\,mol\,dm^{-3}$ sodium thiosulfate, $Na_2S_2O_3$.

$$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow Na_2S_4O_6(aq) + 2NaI(aq)$$
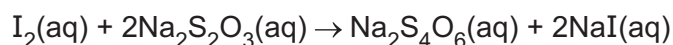
(a) (i) Complete Table 1.1 and determine the mean titre to be used in calculating the concentration of dissolved oxygen.

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 = ... cm^3 [2]

(ii) Calculate the concentration of dissolved oxygen in the $25.0\,cm^3$ of solution.
Show your working.

concentration of dissolved oxygen in $25.0\,cm^3$ 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 × 10^{-4} / 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.
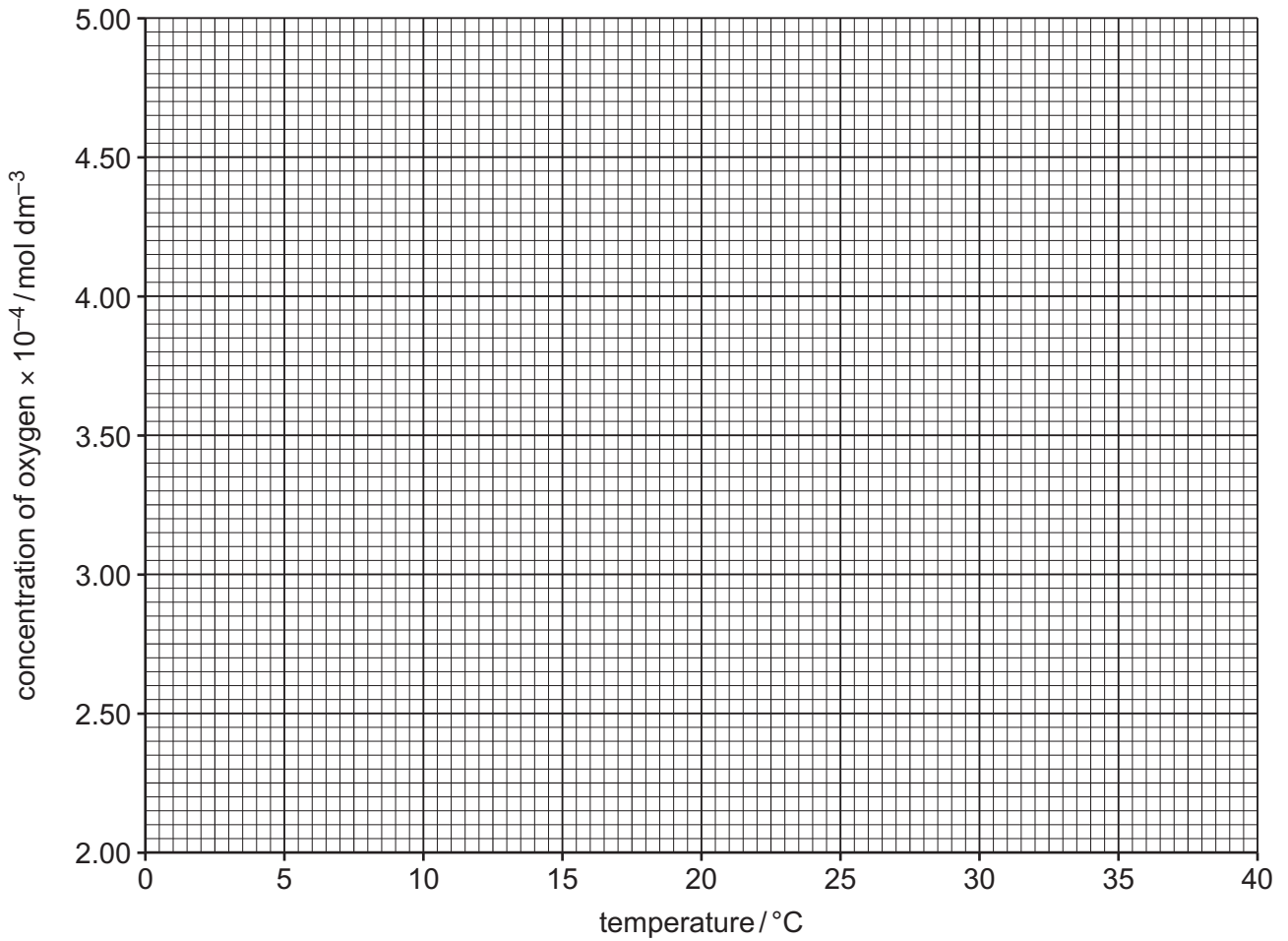
[2]

(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, $C_6H_5N_2Cl$, decomposes in water as shown in the following equation.

$$C_6H_5N_2Cl(aq) + H_2O(l) \rightarrow C_6H_5OH(aq) + N_2(g) + HCl(aq)$$
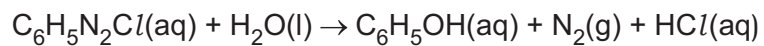
A solution of $0.0750\,\text{mol}\,\text{dm}^{-3}$ of $C_6H_5N_2Cl(aq)$ decomposes at a constant temperature of $50\,°C$. The volume of nitrogen gas, $N_2(g)$, collected is recorded every 5 minutes for 45 minutes.

(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.
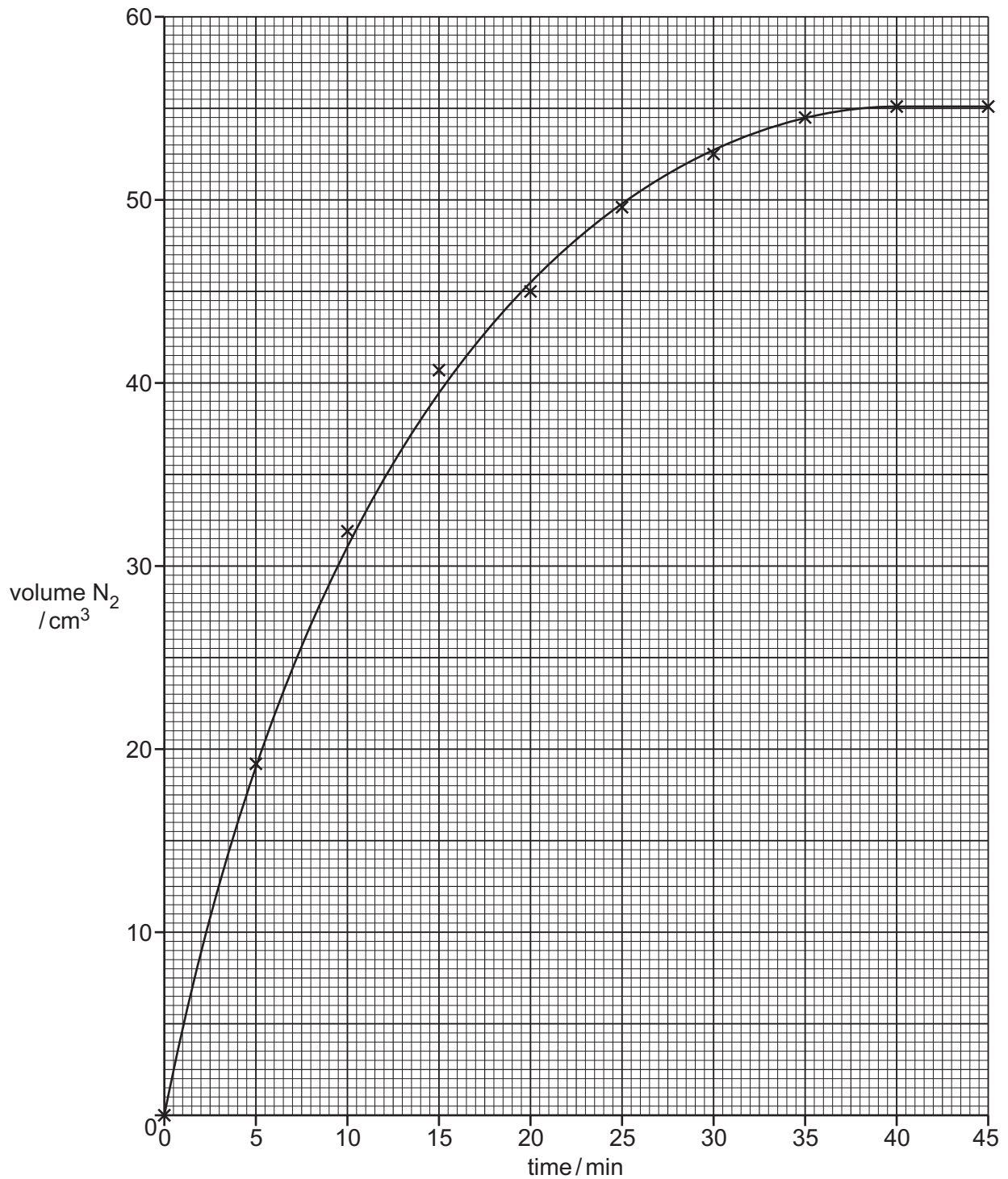

Fig. 2.1

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

initial rate of reaction = ... $cm^3\,min^{-1}$ [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 $0.0375 \, mol \, dm^{-3}$ $C_6H_5N_2Cl(aq)$ 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 $C_6H_5N_2Cl(aq)$ at 50 °C. He measures the time taken to collect $0.0150 \, dm^3$ of $N_2(g)$ 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 $C_6H_5N_2Cl(aq)$ / $mol \, dm^{-3}$	time taken to collect $0.0150 \, dm^3$ of N_2/s	rate of N_2 production / $dm^3 \, s^{-1}$
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.

$$\text{rate} = k\,[C_6H_5N_2Cl]$$

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 $0.200\,\text{mol dm}^{-3}$ $C_6H_5N_2Cl$(aq).

Describe how the student should make a standard solution of $100.0\,\text{cm}^3$ of $0.200\,\text{mol dm}^{-3}$ $C_6H_5N_2Cl$(aq) starting from a solution of $0.500\,\text{mol dm}^{-3}$ $C_6H_5N_2Cl$(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 $100.0\,\text{cm}^3$.

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) $C_6H_5N_2Cl$ 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.
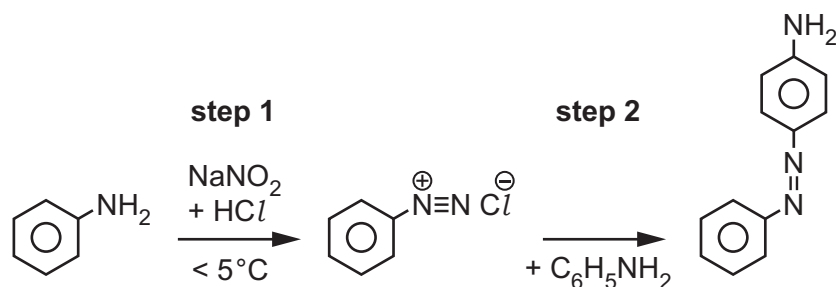

Fig. 2.2

In **step 1**, phenylamine, $C_6H_5NH_2$, is converted into $C_6H_5N_2Cl$.

In **step 2**, $C_6H_5N_2Cl$ is reacted with more $C_6H_5NH_2$ 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	$R = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4\,\text{C}\,\text{mol}^{-1}$
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	$c = 4.18\,\text{kJ}\,\text{kg}^{-1}\,\text{K}^{-1}$ (4.18 J g^{-1} K^{-1})

The Periodic Table of Elements

Group

Key

atomic number
atomic symbol
name
relative atomic mass

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 –