Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME											
CENTRE NUMBER							CANDIDATE NUMBER				

1373946311

CHEMISTRY **9701/51**

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.

This document has **12** pages.

DC (SL) 333098

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 1.00×10^{-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.

....

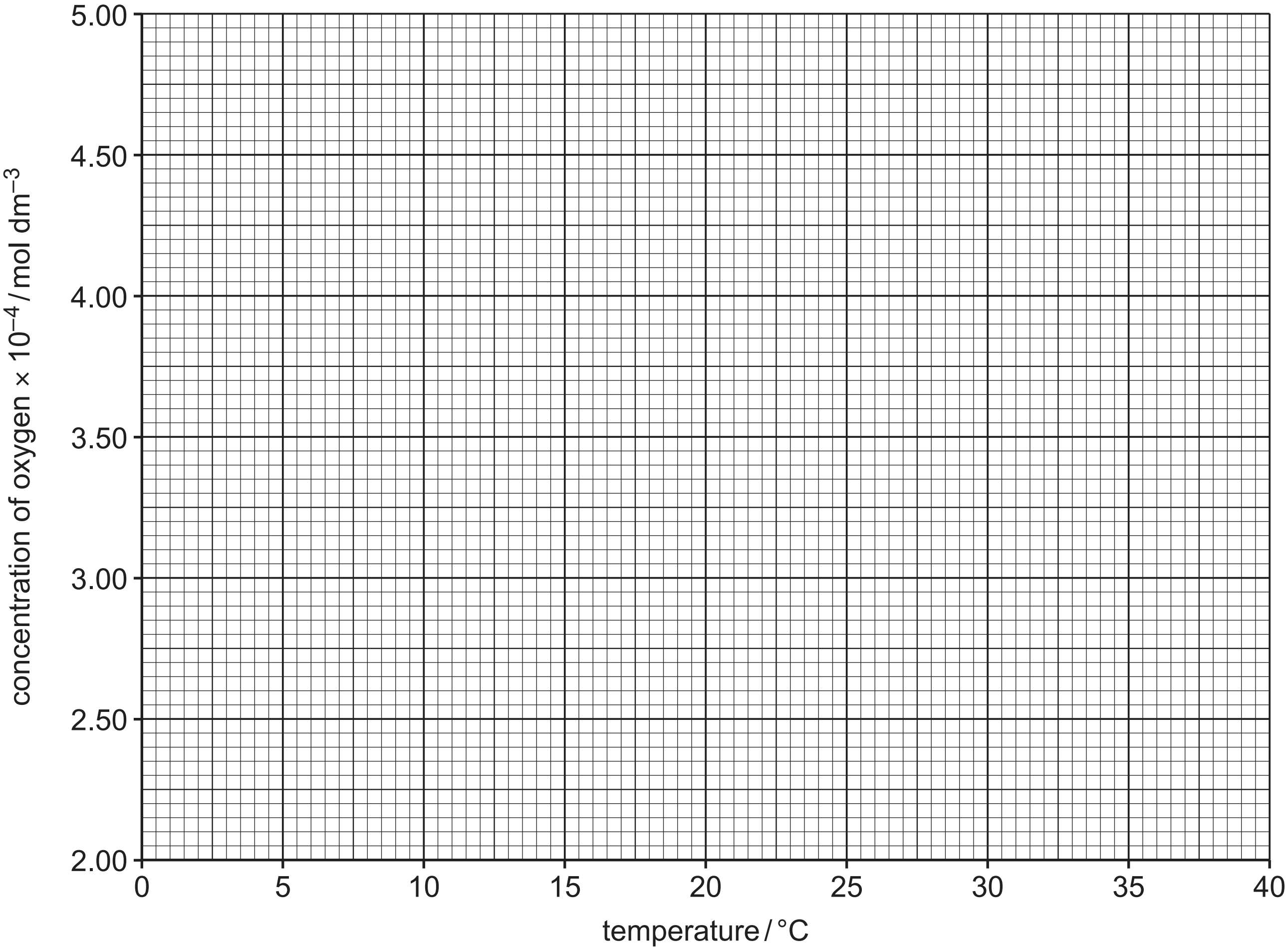
.... [1]

(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 $mol\,dm^{-3}$ 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.

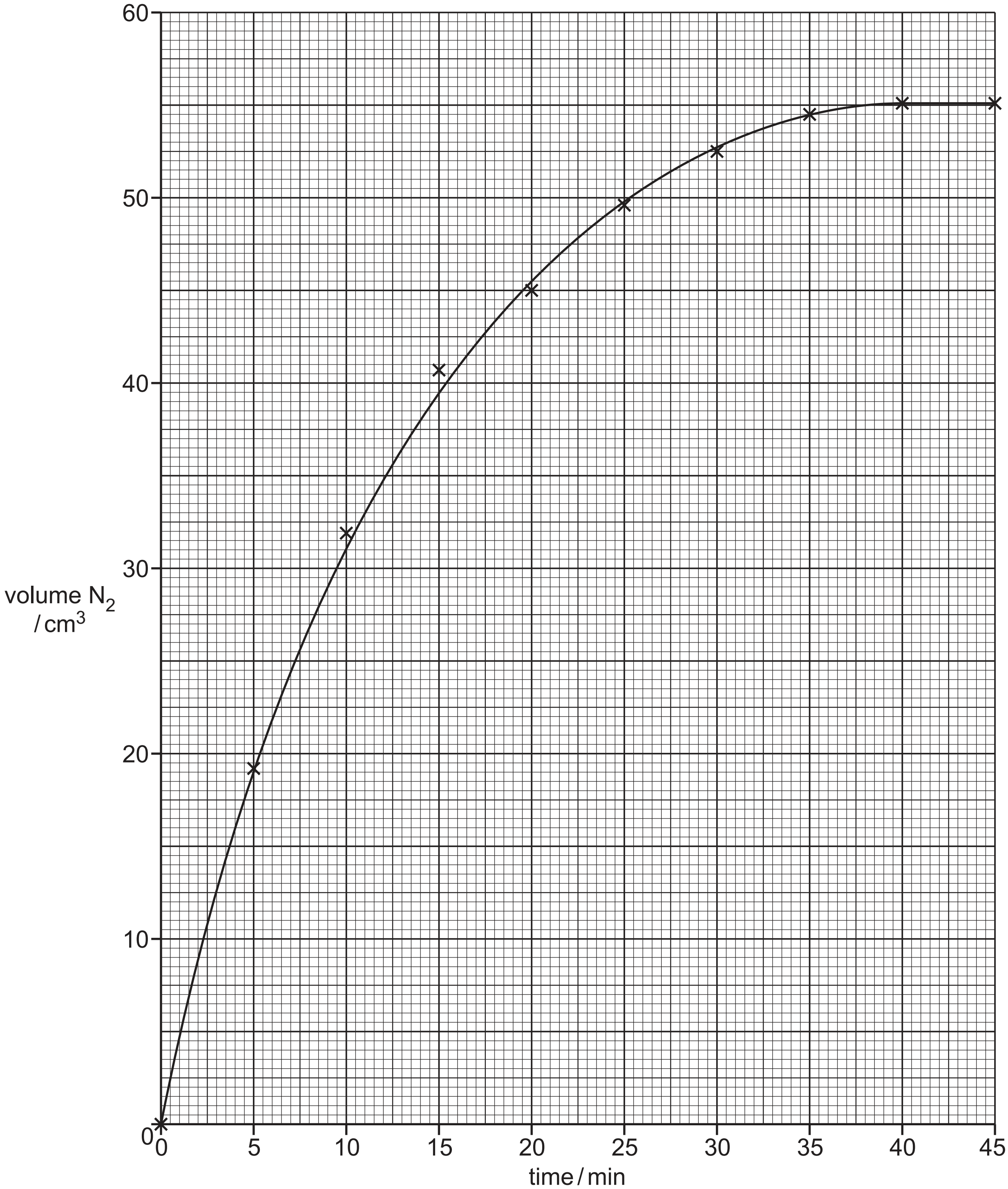


Fig. 2.1

(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 mol dm^{-3} $C_6H_5N_2Cl$(aq).

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

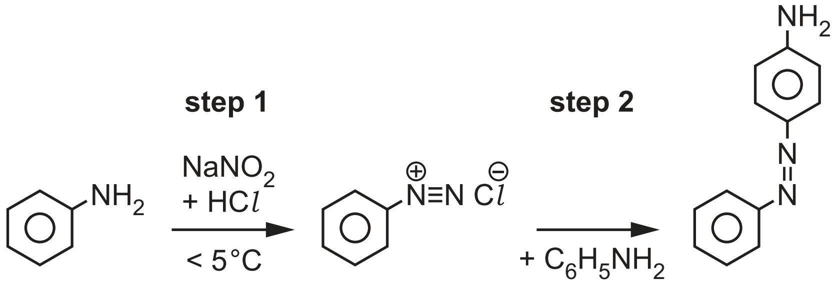


Fig. 2.2

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

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 144.4	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 –