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CAMBRIDGE International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **May/June 2026**

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. Do **not** use correction fluid or tape.
- 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/CT) 354245/4

[Turn over

1 Solid mixture **X** contains **only** anhydrous calcium chloride, $CaCl_2$, and anhydrous calcium nitrate, $Ca(NO_3)_2$. An experiment is done to find the percentage by mass of $Ca(NO_3)_2$ in the mixture.

step 1 Weigh an empty crucible. Add approximately 5 g of mixture **X** to the crucible.

step 2 Reweigh the crucible with mixture **X**.

step 3 Heat the crucible gently for one minute and then strongly for four minutes. The calcium nitrate decomposes.

$$2Ca(NO_3)_2(s) \rightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

step 4 Allow the crucible to cool. Reweigh the crucible and contents.

(a) Identify the piece of apparatus that should be used to support the crucible during heating in step 3.

.... [1]

(b) Suggest why heating is gentle at first in step 3.

.... [1]

(c) Give **one** reason why the heating should be done in a fume hood.

.... [1]

(d) The student carries out the experiment and obtains the results shown in Table 1.1.

Table 1.1

	mass / g
mass of crucible	12.74
mass of crucible + contents before heating	17.81
mass of crucible + contents after heating	16.53

(i) Use the data from Table 1.1 to calculate the amount, in mol, of NO_2 gas lost during heating.

amount of NO_2 lost = ... mol [2]

(ii) Calculate the percentage error in the measurement of the mass of the crucible + contents before heating.

Show your working.

percentage error = ... % [1]

(iii) Other than changing the apparatus, suggest how the percentage error in **1(d)(ii)** can be reduced.

.... [1]

(e) The experiment is repeated using 4.98 g of mixture **X**. In this experiment, 0.0223 mol of NO_2 gas is lost during heating.

Calculate the percentage by mass of $Ca(NO_3)_2$ in this sample of mixture **X**.

[M_r: $Ca(NO_3)_2$, 164.1]

percentage by mass of $Ca(NO_3)_2$ = ... % [2]

(f) **(i)** Suggest **one** additional step that should be done to ensure that the $Ca(NO_3)_2$ has completely thermally decomposed.

.... [1]

(ii) State the effect on the percentage by mass of $Ca(NO_3)_2$ calculated in **1(e)** if the $Ca(NO_3)_2$ is **not** completely thermally decomposed. Explain your answer.

....

.... [1]

(g) A student wants to collect the NO_2 gas produced by the thermal decomposition of a sample of mixture **X** by cooling the gas mixture produced until the NO_2 condenses and the oxygen does **not**.

Table 1.2

	melting point / °C	boiling point / °C
nitrogen dioxide	–11	21
oxygen	–219	–183

Complete Figure 1.1 to show a labelled diagram of the laboratory apparatus that could be used to prepare liquid NO_2 from mixture **X**.

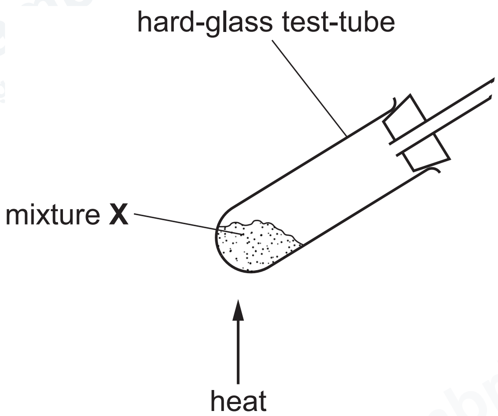

Figure 1.1

[2]

[Total: 13]

2 Ozone, $O_3(g)$, is a pollutant at ground level. Some experiments are done to determine the concentration of $O_3(g)$ in the air outside a school at different times of day.

The method involves bubbling a sample of air through a solution of acidified iodide ions, $I^-(aq)$. Any $O_3(g)$ in the sample of air reacts to form triiodide ions, $I_3^-(aq)$.

$$O_3(g) + 3I^-(aq) + 2H^+(aq) \rightarrow I_3^-(aq) + O_2(g) + H_2O(l)$$

When starch solution is added to the mixture, it forms a coloured complex with $I_3^-(aq)$ ions. The concentration of $I_3^-(aq)$ is found by colorimetry and the percentage of $O_3(g)$ in the air is determined.

A diagram of the colorimeter used is shown in Figure 2.1.

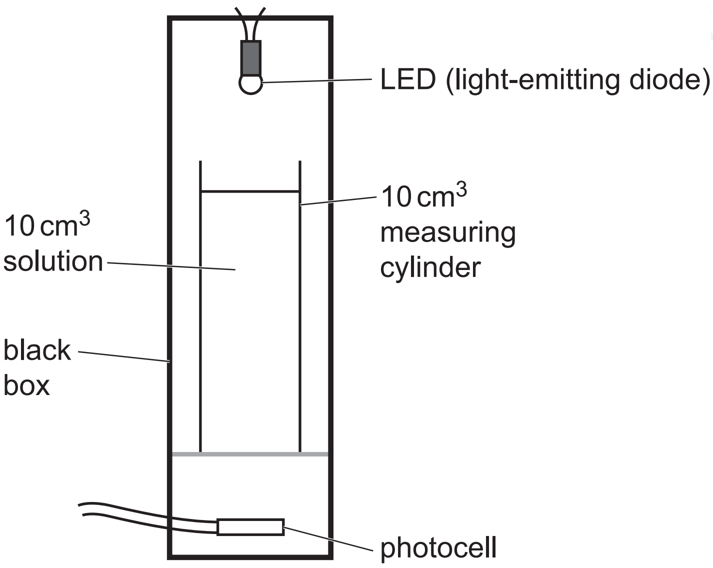

Figure 2.1

In the colorimeter, light from the LED passes through the solution in the measuring cylinder. Some of the light is absorbed by the complex containing starch and I_3^- ions. The photocell is used to determine the absorbance of the solution in the measuring cylinder.

(a) Suggest **one** reason why the colorimeter must be enclosed in a black box.

....

.... [1]

(b) To calibrate the colorimeter shown in Figure 2.1, five solutions of different known concentrations of I_3^-(aq) are prepared. For each solution, the following procedure is carried out.

step 1 Place 15.0 cm^3 of I_3^-(aq) solution in a boiling tube.

step 2 Add a few drops of starch solution to the boiling tube so that I_3^-(aq) ions form a coloured complex.

step 3 Wait for ten minutes.

step 4 Transfer 10.0 cm^3 of solution from the boiling tube to a 10 cm^3 measuring cylinder.

step 5 Place the measuring cylinder into the colorimeter.

step 6 Switch on the LED and record the resistance of the photocell.

The known concentrations of I_3^-(aq) used and the resistance readings of the photocell, R_s, are shown in Table 2.1.

The absorbance, A, of each solution is calculated using equation 1.

equation 1 $A = \log(R_s / R_0)$

R_0 is the resistance measured in a control experiment. The value of R_0 in this experiment is 4.85 kΩ.

Table 2.1

concentration of I_3^-(aq) / mol dm^{-3}	resistance of photocell, R_s / kΩ	absorbance, A
3.60×10^{-6}	33.46	
2.94×10^{-6}	23.42	
2.20×10^{-6}	16.01	
1.52×10^{-6}	9.68	
7.90×10^{-7}	7.50	

(i) Complete Table 2.1.
Record your values to **three** significant figures. [1]

(ii) Suggest what was placed in the measuring cylinder in Figure 2.1 to obtain the value for R_0.

.... [1]

(iii) State the independent variable.

.... [1]

(iv) Use the results from Table 2.1 to plot a graph on the grid in Figure 2.2 to show the relationship between absorbance, A, and the concentration of I_3^-(aq). Use a cross (×) to plot each data point. Draw a line of best fit. [2]

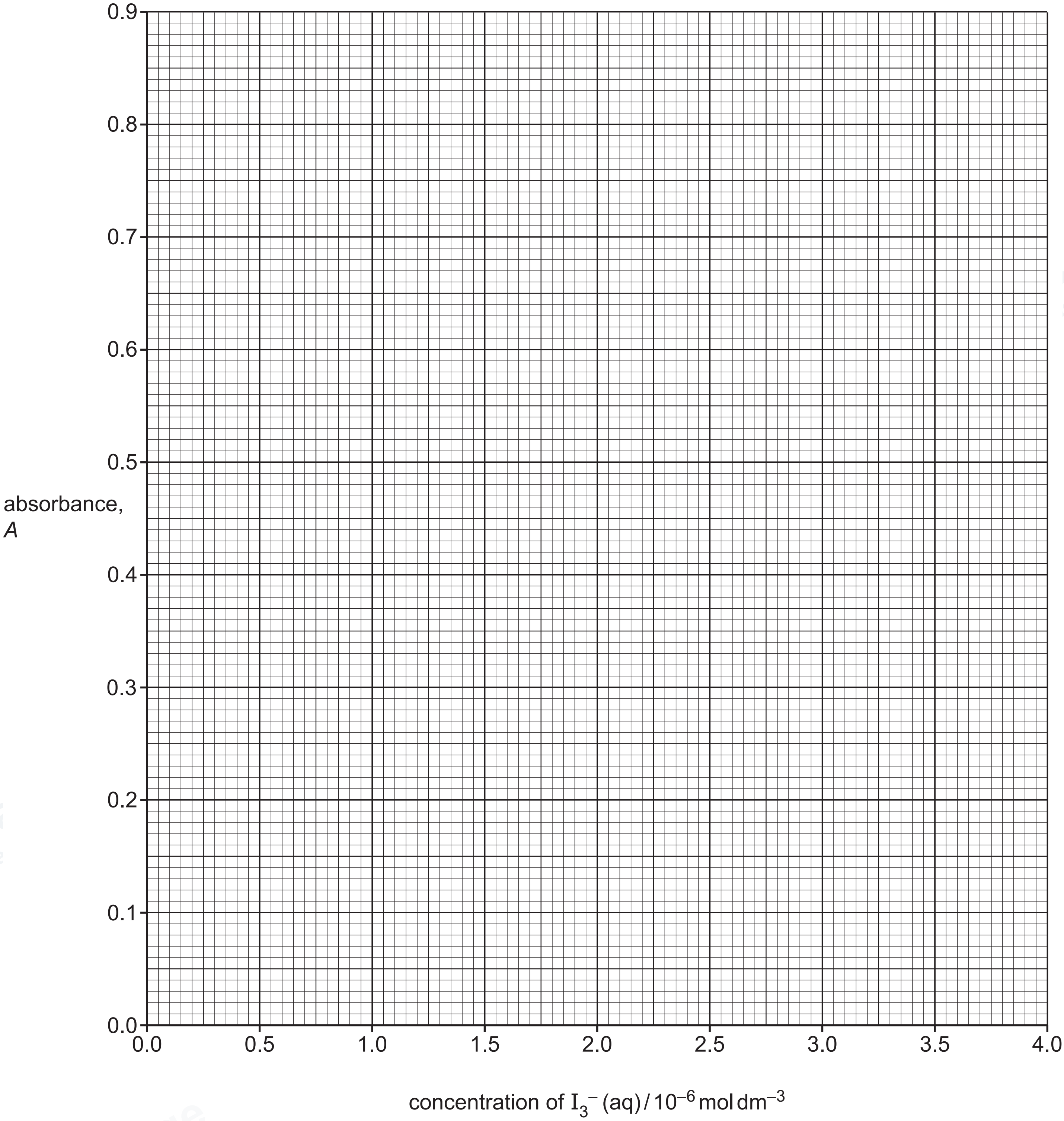

Figure 2.2

(v) Circle the most anomalous point on the graph in Figure 2.2.
Suggest **one** reason to explain the anomalous point you have circled.
Assume no error was made in preparing the I_3^-(aq) solution.

.... [1]

(c) The following procedure is used to determine the concentration of O_3(g) in each sample of air.

step 1 Bubble air through a boiling tube containing 15.0 cm^3 of acidified aqueous iodide ions, I^-(aq), for 30 minutes, as shown in Figure 2.3.

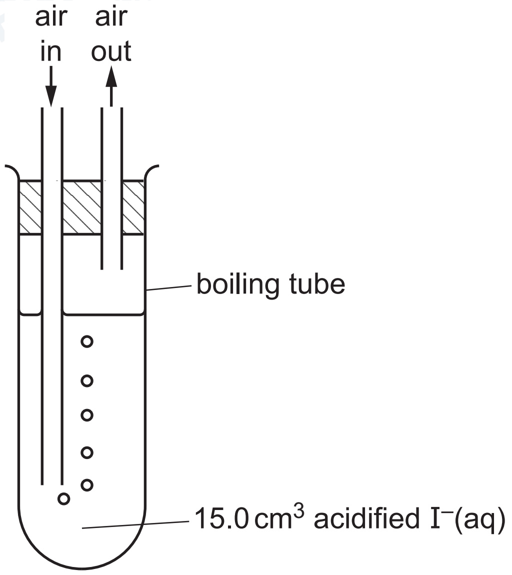

Figure 2.3

Repeat steps 2–6 from the procedure in **2(b)**.

(i) Suggest a reason for waiting ten minutes after the starch solution is added (step 3).

.... [1]

(ii) Identify the most appropriate piece of apparatus to transfer 10.0 cm^3 of the solution from the boiling tube to a 10 cm^3 measuring cylinder (step 4).

.... [1]

(iii) A student follows the procedure and measures the photocell resistance, R_s, as 21.17 kΩ.

Use this information and your graph in Figure 2.2 to find the concentration, in mol dm^{-3}, of I_3^-(aq).

concentration of I_3^-(aq) = ... mol dm^{-3} [2]

(iv) Use your answer to **2(c)(iii)** to calculate the amount, in mol, of O_3(g) in the air bubbled through the boiling tube.

amount of O_3(g) = ... mol [1]

(v) In step 1 in **2(c)**, the volume of air bubbled through the boiling tube in 30 minutes is 7500 cm^3.

Use your answer to **2(c)(iv)** to calculate the concentration, in mol dm^{-3}, of O_3(g) in the air.

[If you were unable to determine an answer to **2(c)(iv)**, then use amount of O_3(g) as 3.23×10^{-8} mol. This may **not** be the correct answer.]

concentration of O_3(g) = ... mol dm^{-3} [1]

(vi) A student draws the line of best fit on the calibration graph that has a gradient which is too low.

State the effect, if any, on the calculated value for the concentration of O_3(g). Explain your answer.

....

.... [1]

(vii) The procedure is repeated at different times of day. The resistances of the photocell are shown in Table 2.2.

Table 2.2

time of day	resistance of photocell, R_s / kΩ
08:00	9.87
12:00	13.66

The total percentage error of each of the resistance readings is determined to be 14.0%. Use this value and the data from Table 2.2 to determine whether the difference in the readings at 08:00 and 12:00 can be accounted for by measurement error or whether there is a difference in the concentration of O_3(g) in the air.

Show your working.

.... [1]

(viii) The procedure is repeated using a different type of 10 cm^3 measuring cylinder. The 10 cm^3 measuring cylinder used is narrower and taller than that used in the first experiment.

State the effect, if any, this would have on the value obtained for the resistance of the photocell, R_s. Explain your answer.

....

.... [1]

(ix) The procedure is repeated but air is bubbled for more than 30 minutes in step 1.

Suggest **one** reason why it is better to bubble air through the solution for longer.

.... [1]

[Total: 17]

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 144.2	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 –