Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5438803009

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **May/June 2022**

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. Any blank pages are indicated.

IB22 06_9701_52/6RP

1 A student plans an experiment to find a value for the molar volume, V_m, of hydrogen gas at room conditions.

Hydrogen gas is formed when magnesium reacts with dilute hydrochloric acid, $HCl(aq)$.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The student is provided with the following materials:

- a piece of magnesium ribbon
- $0.50\,mol\,dm^{-3}$ $HCl(aq)$
- a water trough
- a side-arm conical flask
- a $250\,cm^3$ measuring cylinder with $2\,cm^3$ graduations for the collection of gas
- a $50\,cm^3$ measuring cylinder
- a balance that measures to 2 decimal places
- access to any necessary laboratory equipment, except gas syringes.

The student plans the following procedure.

Step 1 Prepare the piece of magnesium ribbon for use in the experiment.

Step 2 Measure $30\,cm^3$ of $HCl(aq)$ and pour into a side-arm conical flask.

Step 3 Attach the conical flask to a collection system for the hydrogen gas.

Step 4 Place the magnesium ribbon in the conical flask.

Step 5 Stopper the flask.

Step 6 Wait until the final volume of gas collected is constant.

Step 7 Wait for an additional 2 minutes, then measure and record the final volume of gas collected.

(a) Complete Fig. 1.1 to show how the apparatus should be assembled for the collection and measurement of gas.
Label your diagram.

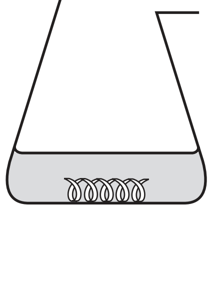


Fig. 1.1

[2]

(b) The surface of the magnesium ribbon has an oxide layer.

(i) State how the student should prepare the piece of magnesium ribbon before it is used in this experiment.

.... [1]

(ii) State what additional information about the magnesium is required before the experiment is performed.

.... [1]

(c) **(i)** Show by calculation that a volume of 30 cm^3 of 0.50 mol dm^{-3} $HCl(aq)$ is enough to react with 0.16 g of magnesium ribbon. Show your working.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

[2]

(ii) State why it is **not** necessary to use a burette to measure 30 cm^3 of 0.50 mol dm^{-3} $HCl(aq)$.

....

.... [1]

(d) The student waits for 2 minutes before taking a reading of the volume.

Suggest why the student waits for 2 minutes before measuring the volume of gas in **step 7**.

....

.... [1]

(e) The student collects 146 cm^3 of hydrogen gas during the experiment.

(i) Calculate the percentage error in collecting the hydrogen gas. Show your working.

percentage error = ... [1]

(ii) Calculate the molar volume of hydrogen gas using the student's results from this experiment.

molar volume = ... cm^3 [1]

(f) The student's experimental value for the molar volume of hydrogen is lower than the value quoted in the table of important values, constants and standards on page 11.

Suggest **one** experimental weakness that might have led to this outcome.

Explain how the method could be improved to overcome the weakness you have noted.

experimental weakness

....

....

improvement

....

....

....

[2]

[Total: 12]

2 In a neutral solution, aqueous potassium iodide acts as a catalyst for the decomposition of aqueous hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

A student plans to carry out an investigation to find how temperature affects the initial rate of the decomposition of aqueous hydrogen peroxide, $H_2O_2(aq)$, in the presence of aqueous potassium iodide, KI(aq).

The student knows that the initial rate of the reaction can be measured by timing the production of the oxygen. The student carries out a series of experiments.

In experiment 1 the student notes the temperature of the $H_2O_2(aq)$ and KI(aq) under room conditions. The solutions are mixed in apparatus designed to collect the oxygen produced. A stop-watch is started at the beginning of the reaction. The volume of oxygen is noted at regular time intervals.

In experiments 2–8 the solutions are heated to different temperatures before mixing and measurement of the oxygen produced.

The data collected is used to determine a value for the activation energy of the decomposition of $H_2O_2(aq)$ in the presence of KI(aq).

(a) State the independent variable.

.... [1]

(b) State **two** variables that need to be controlled.

1 ....

2 ....
[2]

(c) **(i)** State how the student should prepare $250.0\,cm^3$ of $0.100\,mol\,dm^{-3}$ $H_2O_2(aq)$ from $0.500\,mol\,dm^{-3}$ $H_2O_2(aq)$.

Calculate the minimum volume of $0.500\,mol\,dm^{-3}$ $H_2O_2(aq)$ required for preparation of the $0.100\,mol\,dm^{-3}$ H_2O_2 solution. Give the name and capacity of any key apparatus which should be used.

Write your answer as a series of numbered steps.

....

....

....

....

....

.... [3]

(ii) Hydrogen peroxide causes eye and skin irritation.

State what precaution should be taken when preparing the solution in **(c)(i)** other than wearing goggles.

.... [1]

(d) **(i)** The student performs experiments 1–8 using a range of temperatures.

The results are shown in Table 2.1.

Complete the table and record the values of $\frac{1}{T}$ to **three** significant figures and the values of log initial rate to **three** significant figures.

Table 2.1

experiment number	temperature / °C	temperature / K	$\frac{1}{T}$ / K^{-1}	initial rate / $mol\,s^{-1}$	log initial rate
1	20	293		5.75×10^{-6}	
2	25	298		7.94×10^{-6}	
3	30	303		1.17×10^{-5}	
4	35	308		1.45×10^{-5}	
5	39	312		2.19×10^{-5}	
6	46	319		3.72×10^{-5}	
7	52	325		5.25×10^{-5}	
8	55	328		6.31×10^{-5}	

[2]

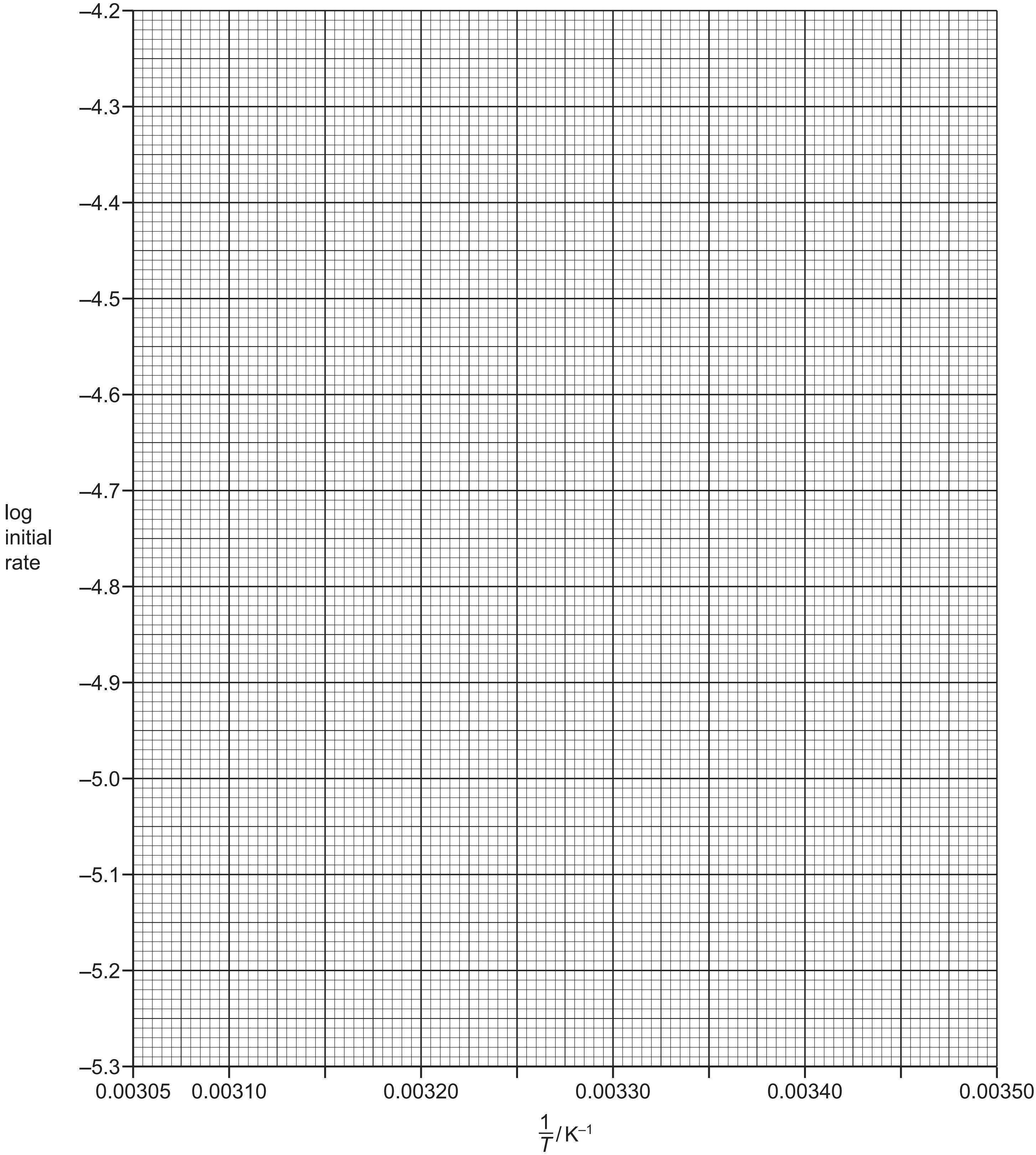
(ii) Plot a graph on the grid to show the relationship between log initial rate and $\frac{1}{T}$.
Use a cross (×) to plot each data point. Draw a line of best fit. [2]

(iii) Circle the point on the graph you consider to be most anomalous.

Suggest **one** reason why this anomaly may have occurred during this experimental procedure.

....

.... [2]



log initial rate
−4.2
−4.3
−4.4
−4.5
−4.6
−4.7
−4.8
−4.9
−5.0
−5.1
−5.2
−5.3
0.00305
0.00310
0.00320
0.00330
0.00340
0.00350
1/T / K⁻¹

(iv) Determine the gradient of your line of best fit. State the coordinates of both points you used in your calculation. These must be selected from your line of best fit.
Give the gradient to **three** significant figures.

coordinates 1 .... coordinates 2 ....

gradient = ... K
[2]

(v) The relationship between log initial rate and $\frac{1}{T}$ is given by the expression:

$$\text{log initial rate} = \text{constant} - \frac{E_a}{2.303\,RT}$$

Use the gradient calculated in **(d)(iv)** to calculate a value for the activation energy, E_a.

(If you were unable to obtain an answer to **(d)(iv)** you may use the value –3100 K. This is **not** the correct value.)

E_a = ... kJ mol^{-1} [2]

(e) It is **not** possible to repeat the investigation.

State whether the data from the investigation is reliable. Justify your answer.

....

.... [1]

[Total: 18]

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Important values, constants and standards

molar gas constant	R = 8.31 J K^{-1} mol^{-1}
Faraday constant	F = 9.65 × 10^{4} C mol^{-1}
Avogadro constant	L = 6.022 × 10^{23} mol^{-1}
electronic charge	e = –1.60 × 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 × 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 –