

Cambridge Assessment
International Education

Cambridge International AS & A Level

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CHEMISTRY**9701/52**

Paper 5 Planning, Analysis and Evaluation

May/June 2022**1 hour 15 minutes**

You must answer on the question paper.

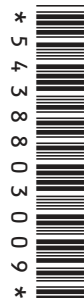
No additional materials are needed.

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

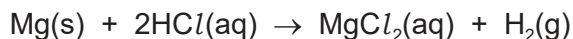
- The total mark for this paper is 30.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **12** pages. Any blank pages are indicated.

2

- 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, $\text{HCl}(\text{aq})$.



The student is provided with the following materials:

- a piece of magnesium ribbon
- $0.50 \text{ mol dm}^{-3} \text{ HCl}(\text{aq})$
- 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 $\text{HCl}(\text{aq})$ 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.

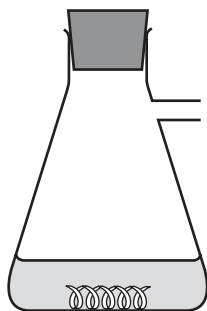


Fig. 1.1

[2]

3

(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 cm³ of 0.50 mol dm⁻³ HCl(aq) is enough to react with 0.16 g of magnesium ribbon. Show your working.



[2]

- (ii) State why it is **not** necessary to use a burette to measure 30 cm³ 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]

4

(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]

5

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



A student plans to carry out an investigation to find how temperature affects the initial rate of the decomposition of aqueous hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$, in the presence of aqueous potassium iodide, $\text{KI}(\text{aq})$.

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 $\text{H}_2\text{O}_2(\text{aq})$ and $\text{KI}(\text{aq})$ 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 $\text{H}_2\text{O}_2(\text{aq})$ in the presence of $\text{KI}(\text{aq})$.

- (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} $\text{H}_2\text{O}_2(\text{aq})$ from 0.500 mol dm^{-3} $\text{H}_2\text{O}_2(\text{aq})$.

Calculate the minimum volume of 0.500 mol dm^{-3} $\text{H}_2\text{O}_2(\text{aq})$ 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]

6

- (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	$\frac{1}{T}/\text{K}^{-1}$	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]

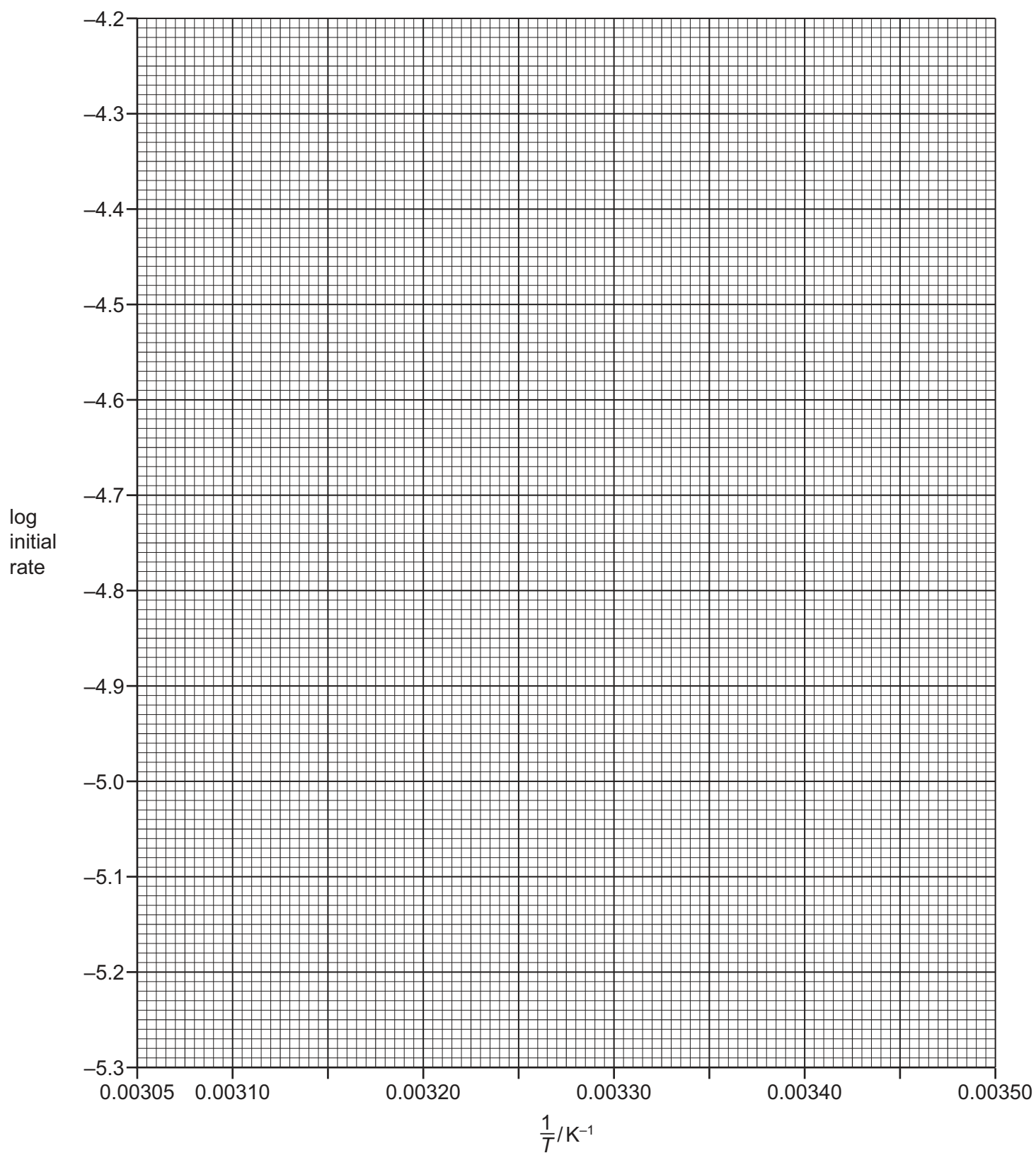
- (iii) Circle the point on the graph you consider to be most anomalous.

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

.....

..... [2]

7



8

- (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:

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

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.)

$E_a = \dots\dots\dots \text{ kJ mol}^{-1}$ [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	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
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)

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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	europtium	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	yterbium	173.1
71	Lu	lutetium	175.0
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	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	—

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	europtium	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	yterbium	173.1
71	Lu	lutetium	175.0
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	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	—