Cambridge Assessment International Education

Example Responses – Paper 5

Cambridge International AS & A Level Chemistry 9701

For examination from 2022

Cambridge Pathway

Contents

Introduction

The main aim of this booklet is to exemplify standards for those teaching Cambridge International AS & A Level Chemistry 9701.

This booklet contains responses to all questions from June 2022 Paper 52, which have been written by a Cambridge examiner. Responses are accompanied by a brief commentary highlighting common errors and misconceptions where they are relevant.

The question papers and mark schemes are available to download from the School Support Hub.

9701 June 2022 Question Paper 52

9701 June 2022 Mark Scheme 52

Past exam resources and other teaching and learning resources are available from the School Support Hub.

Question 1

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.

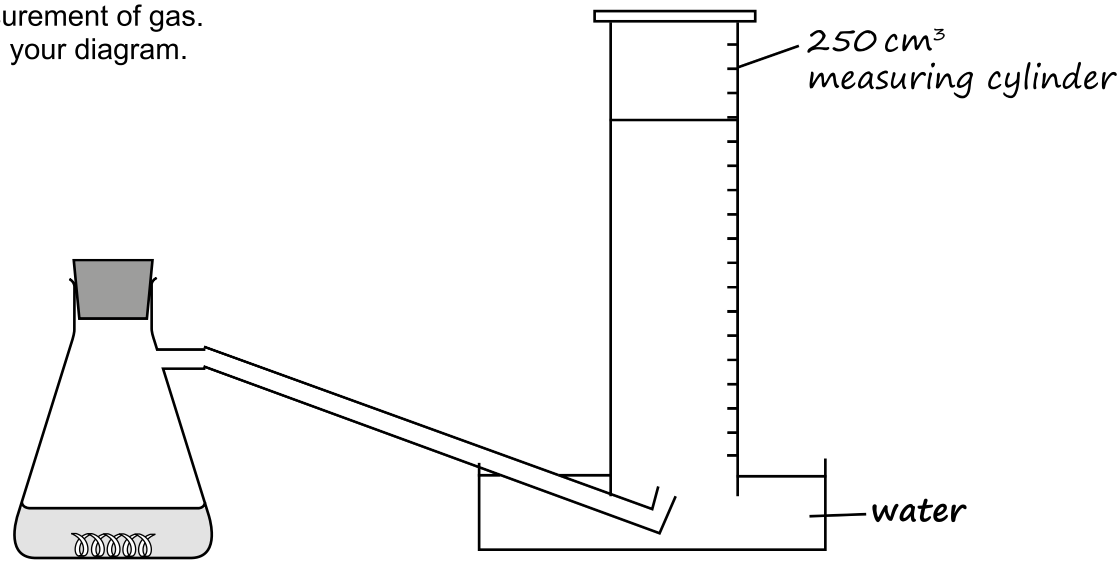


Fig. 1.1

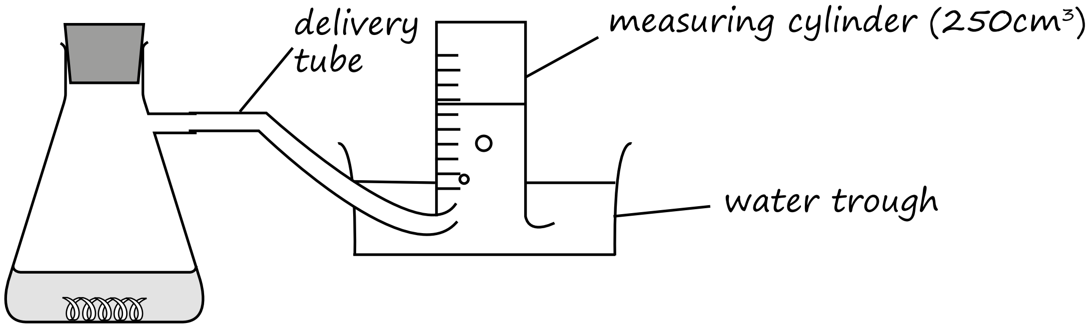
[2]

Examiner comment

Candidates were required to complete a simple diagram showing how to collect a measured volume of hydrogen gas by displacement of water from an inverted measuring cylinder.

The diagram needed to show sealed apparatus. The only essential labelling was the measuring cylinder in which the gas was collected.

An example of where the delivery tubing passed through the side of the trough is shown.



(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.

Remove the oxide layer by rubbing with sandpaper. [1]

Examiner comment

Candidates were required to describe how the oxide layer should be removed. A common incorrect answer was to suggest removing the oxide layer with dilute acid. Dilute acid would also attack the magnesium.

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

The mass of magnesium ribbon. [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.

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

Mol of HCl used = 0.50 x 30/1000 = 0.0150 mol

Mol of Mg used = 0.16/24.3 = 0.00658 mol

0.0150/2 = 0.0075 mol

0.00658 mol < 0.0075 mol [2]

Examiner comment

There were many acceptable methods of doing this calculation. Most opted to work out the mol of HC*l*, then the mol of Mg followed by a statement that moles of Mg is less than half of moles of HC*l*.

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

It was not necessary to use a burette to measure 30 cm^3 of HCl as the HCl was in excess. [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**.

To make sure the hydrogen gas is at room temperature. [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.

100 x (1/146) = 0.685%

percentage error = 0.685% [1]

Examiner comment

Common errors included:

- not realising that a measuring cylinder requires only one reading. 100 x (1 x 2/146) = 1.37% was seen.
- not realising that half a graduation is the error. 100 x (2/146) and = 1.37% was seen.

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

146 / 0.00658 = 22 174 cm³ = 22 200 cm³

(to three significant figures)

molar volume = ...*22 200*........ cm^3 [1]

Examiner comment

One common error was to use the mol of HCl (0.0150) which was in excess, rather than the mol of Mg (0.00658), which was the limiting reagent.

(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

there was a loss of hydrogen gas before the stopper could be placed in position.

improvement

place the magnesium in a test-tube suspended above the acid before placing the stopper in position. Once the stopper is in position shake the flask to allow the magnesium to drop into the acid.

[2]

Examiner comment

- The question asks why the molar volume was lower than the standard value. This could only come about through gas being lost during the experiment.
- Many candidates incorrectly focused on the inaccuracy of the measuring cylinder, but this may have also given a higher molar volume than the standard value as well as a lower one.

Question 2

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.

temperature .... [1]

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

1 *volume of $H_2O_2(aq)$* *volume of KI(aq)* ....

2 *concentration of $H_2O_2(aq)$* *concentration of KI(aq)* ....

[2]

Examiner comment

A common error was to provide vague responses such as ‘the amount of H_2O_2’ or ‘the amount of KI’.

(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.

Volume of 0.500 mol dm^{-3} $H_2O_2(aq)$ needed = 250 x 0.100/0.500 = 50.0 cm^3.

Use a burette to transfer 50.0 cm^3 of 0.500 mol dm^{-3} $H_2O_2(aq)$ into a 250.0 cm^3 volumetric flask.

Top up the volumetric flask to the 250.0 cm^3 mark using distilled water.

[3]

Examiner comment

- Some candidates opted to use a burette to transfer 50.0 cm^3 of 0.500 mol dm^{-3} $H_2O_2(aq)$ into a beaker and subsequently transferring from the beaker to the volumetric flask. This was acceptable as long as rinsing of the beaker took place.
- Common errors included:
  - using non-volumetric apparatus such as a measuring cylinder to transfer 50.0 cm^3 of 0.500 mol dm^{-3} $H_2O_2(aq)$
  - using a conical flask instead of a volumetric flask
  - rinsing the burette; this would place more than 50.0 cm^3 of 0.500 mol dm^{-3} $H_2O_2(aq)$ into the volumetric flask
  - not rinsing an intermediate beaker if used.

(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.

Wear chemically resistant gloves. [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	0.00341	5.75×10^{-6}	−5.24
2	25	298	0.00336	7.94×10^{-6}	−5.10
3	30	303	0.00330	1.17×10^{-5}	−4.93
4	35	308	0.00325	1.45×10^{-5}	−4.84
5	39	312	0.00321	2.19×10^{-5}	−4.66
6	46	319	0.00313	3.72×10^{-5}	−4.43
7	52	325	0.00308	5.25×10^{-5}	−4.28
8	55	328	0.00305	6.31×10^{-5}	−4.20

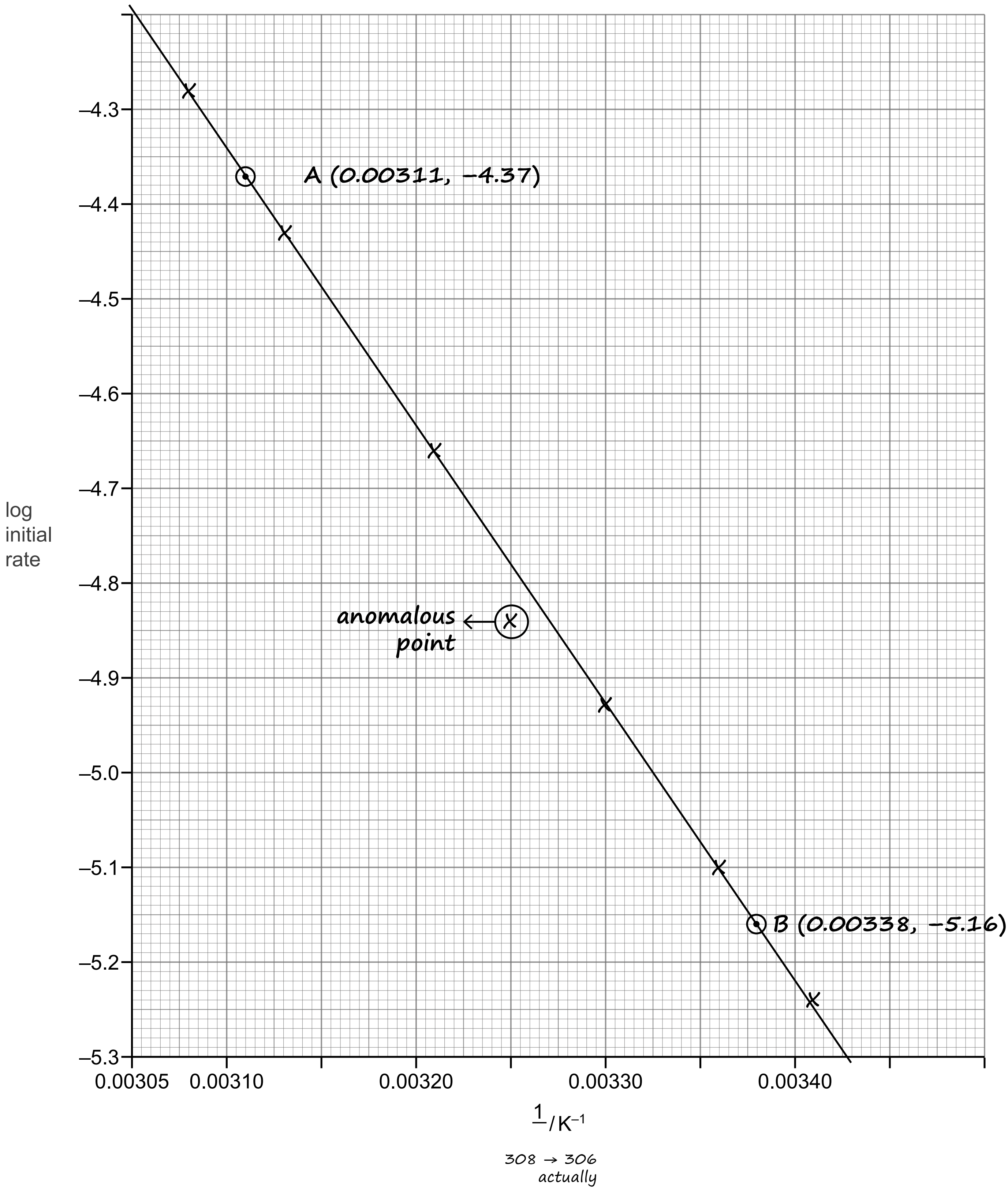
[2]

Examiner comment

Common errors included:

- incorrect rounding of calculated values
- using three decimal places instead of three significant figures.

(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.

The recorded temperature reading is higher than the actual temperature for that set of readings of gas volumes. [2]

Examiner comment

Answers based upon a lack of appreciation that each temperature involved continuous readings of gas volumes so 'The stopwatch was stopped early' was clearly incorrect as a stopwatch was not stopped.

(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 (0.00311, −4.37) coordinates 2 (0.00338, −5.16)

$$\text{Gradient} = \frac{(-5.16)-(-4.37)}{0.00338-0.00311} = -2926\ \text{K}$$

gradient = −2930 K
[2]

Examiner comment

Common errors included:

- misreading co-ordinates
- sets of co-ordinates too close together
- transposing the x and y co-ordinates.

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

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

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.)

$$\frac{-E_a}{2.303 \times R} = -2930\,\text{K}$$

E_a = 2.303 x 8.31 x 2926 = 55998 J mol^{-1} = 56.0 kJ mol^{-1}

E_a = ...56.0........ 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.

The investigation is reliable because 7 of the 8 points lie on the line of best fit or very close to it. [1]

OR

The investigation is not reliable because there is an anomalous point.

[Total: 18]

Examiner comment

As can be seen from the two seemingly opposing reasons, it was left to the candidates to interpret whether (only) one anomaly makes an investigation reliable or not.

Cambridge Assessment International Education
The Triangle Building, Shaftesbury Road, Cambridge, CB2 8EA, United Kingdom
t: +44 1223 553554
e: info@cambridgeinternational.org   www.cambridgeinternational.org