Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

3430269783

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2017**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **11** printed pages and **1** blank page.

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CAMBRIDGE International Examinations

[Turn over

1 Iodide ions, I^-, and persulfate ions, $S_2O_8^{2-}$, react according to the following equation.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

The rate of reaction between these ions can be determined from the time it takes for a certain amount of iodine, I_2(aq), to be produced.

- A mixture of solutions is prepared, containing known volumes of
  - aqueous ammonium persulfate, $(NH_4)_2S_2O_8$(aq),
  - aqueous sodium thiosulfate, $Na_2S_2O_3$(aq),
  - starch indicator.
- A known volume of aqueous potassium iodide, KI(aq), is added to this mixture and a timer is started.
- After the reactants are mixed, they react slowly to produce iodine, I_2(aq).
- Any iodine initially produced is removed by a reaction with thiosulfate ions.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

- Iodine, I_2(aq), is continuously removed until all of the thiosulfate ions have been used up.
- After that time any I_2(aq) that is produced turns the starch indicator blue.
- The time of the first appearance of the blue colour is recorded.
- This procedure is repeated with different volumes of reactants, keeping the total volume of the reaction mixture constant by adding the required volume of distilled water.

You are to plan a series of experiments to determine the effect of changing the concentration of iodide ions on the rate of reaction.

You are provided with the following materials.

solid ammonium persulfate, $(NH_4)_2S_2O_8$(s)
0.20 mol dm^{-3} aqueous KI, a source of I^-(aq)
0.0050 mol dm^{-3} aqueous $Na_2S_2O_3$, a source of $S_2O_3^{2-}$(aq)
starch indicator

(a) **(i)** Calculate the mass of $(NH_4)_2S_2O_8$(s) that would be required to prepare 250 cm^3 of a standard solution of concentration 1.00 mol dm^{-3}.

[A_r values: N, 14.0; H, 1.0; S, 32.1; O, 16.0]

mass of $(NH_4)_2S_2O_8$(s) = ... g [1]

(ii) Describe how, after weighing the mass calculated in **(i)**, you would prepare this standard solution for use in your experiment.

Give the name and capacity, in cm^3, of any apparatus used.

....

....

....

....

.... [2]

(iii) Explain how the use of starch solution improves the accuracy of the experiment.

....

....

.... [1]

(b) A student planned five experiments to investigate the effect of iodide concentration, $[I^-]$, on the rate of reaction. The table shows the volumes used in experiment **1**.

Complete the table for experiments **2** to **5**.

experiment	volume of 1.00 mol dm^{-3} $(NH_4)_2S_2O_8(aq)$ / cm^3	volume of 0.20 mol dm^{-3} $KI(aq)$ / cm^3	volume of water / cm^3	volume of 0.0050 mol dm^{-3} $Na_2S_2O_3(aq)$ / cm^3	volume of starch solution / cm^3
1	25.0	10.0	0.0	5.0	1.0
2				5.0	1.0
3				5.0	1.0
4				5.0	1.0
5				5.0	1.0

[3]

(c) In a different experiment, a student mixed the following solutions and measured the time taken for the reaction.

- $10.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ $(NH_4)_2S_2O_8(aq)$
- $5.0\,cm^3$ of $0.0050\,mol\,dm^{-3}$ $Na_2S_2O_3(aq)$
- $5.0\,cm^3$ of $0.20\,mol\,dm^{-3}$ KI(aq)
- $1.0\,cm^3$ of starch indicator

(i) The time taken for the blue colour to appear was 134 seconds (to the nearest second).

Calculate the rate of production of moles of I_2, in $mol\,dm^{-3}\,s^{-1}$.

rate of production of moles of I_2 = ... $mol\,dm^{-3}\,s^{-1}$ [3]

(ii) What should the student have done to make sure that the results were reliable?

....

.... [1]

(iii) The $5.0\,cm^3$ of $0.0050\,mol\,dm^{-3}$ $Na_2S_2O_3(aq)$ was measured using a $50\,cm^3$ burette which had graduations every $0.1\,cm^3$.

Calculate the maximum percentage error in the measured volume of this solution.

percentage error = ... % [1]

(d) A second student tried to perform the same experiment but found that the reaction mixture turned blue immediately after KI(aq) was added.

State what error the student had made.

....

.... [1]

(e) The following information gives some of the hazards associated with the chemicals used in the procedure.

Ammonium persulfate	Solid is **oxidising** and **hazardous to the environment**. Contact with combustible material may cause fire. It is classified as **health hazard**, is harmful if swallowed and is irritating to eyes, respiratory system and skin. Solutions equal to or more concentrated than 0.2 mol dm^{-3} should be labelled **health hazard** and **hazardous to the environment**. Solutions equal to or more concentrated than 0.05 mol dm^{-3} but less concentrated than 0.2 mol dm^{-3} should be labelled **health hazard**.
Potassium iodide	All solutions are low hazard.
Sodium thiosulfate	All solutions are low hazard.

Describe **one** relevant precaution, other than eye protection and a lab coat, that should be taken to keep the risk associated with the chemicals used to a minimum. Explain your answer.

....

....

.... [1]

[Total: 14]

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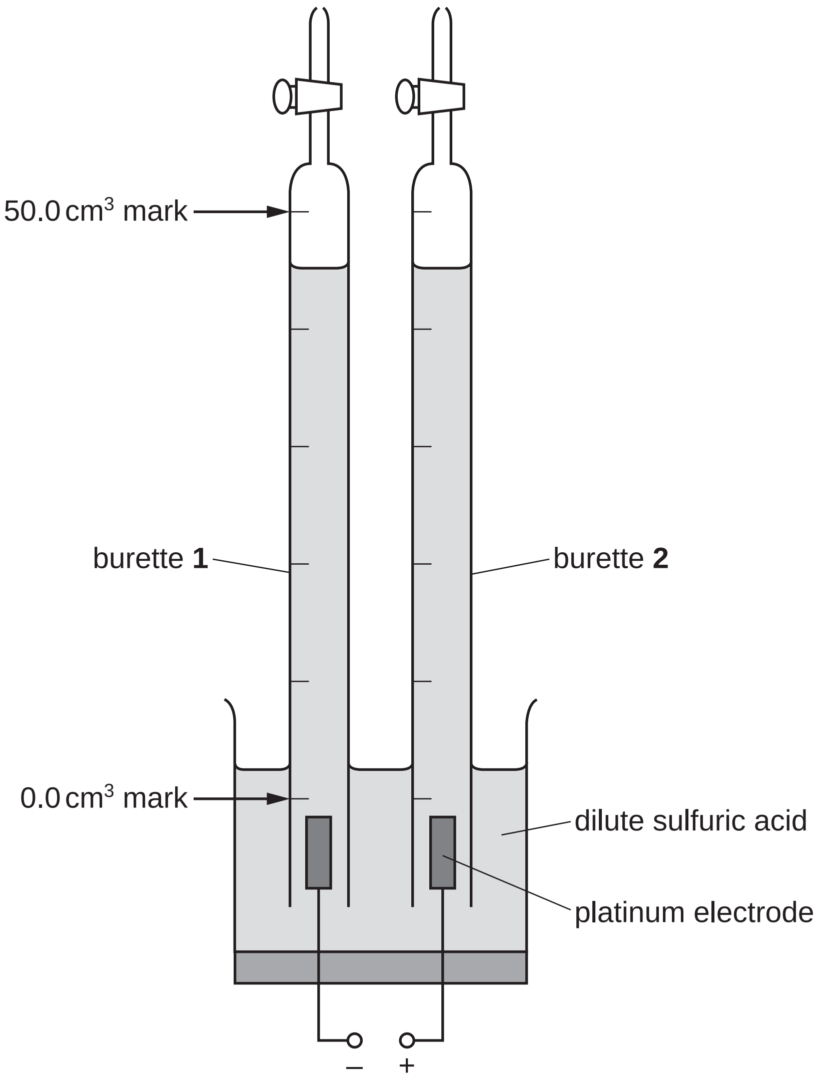
2 Dilute sulfuric acid, $H_2SO_4(aq)$, can be electrolysed using platinum electrodes and a direct current. Hydrogen gas is produced at the cathode and oxygen gas is produced at the anode. The two gases are collected separately in burettes filled with dilute sulfuric acid placed over each electrode.



reaction at electrode in burette **1**: $2H^+(aq) + 2e^- \rightarrow H_2(g)$
reaction at electrode in burette **2**: $H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$

The production of hydrogen gas over time can be measured, and the data used to determine the charge of one mole of electrons, known as the Faraday constant, *F*.

(a) The volumes of hydrogen gas produced during the electrolysis process are recorded in the table.

Process the results to calculate the volume of hydrogen gas produced, in cm^3, and the charge passed, in coulombs, C.

charge (C) = current (A) × time (s)

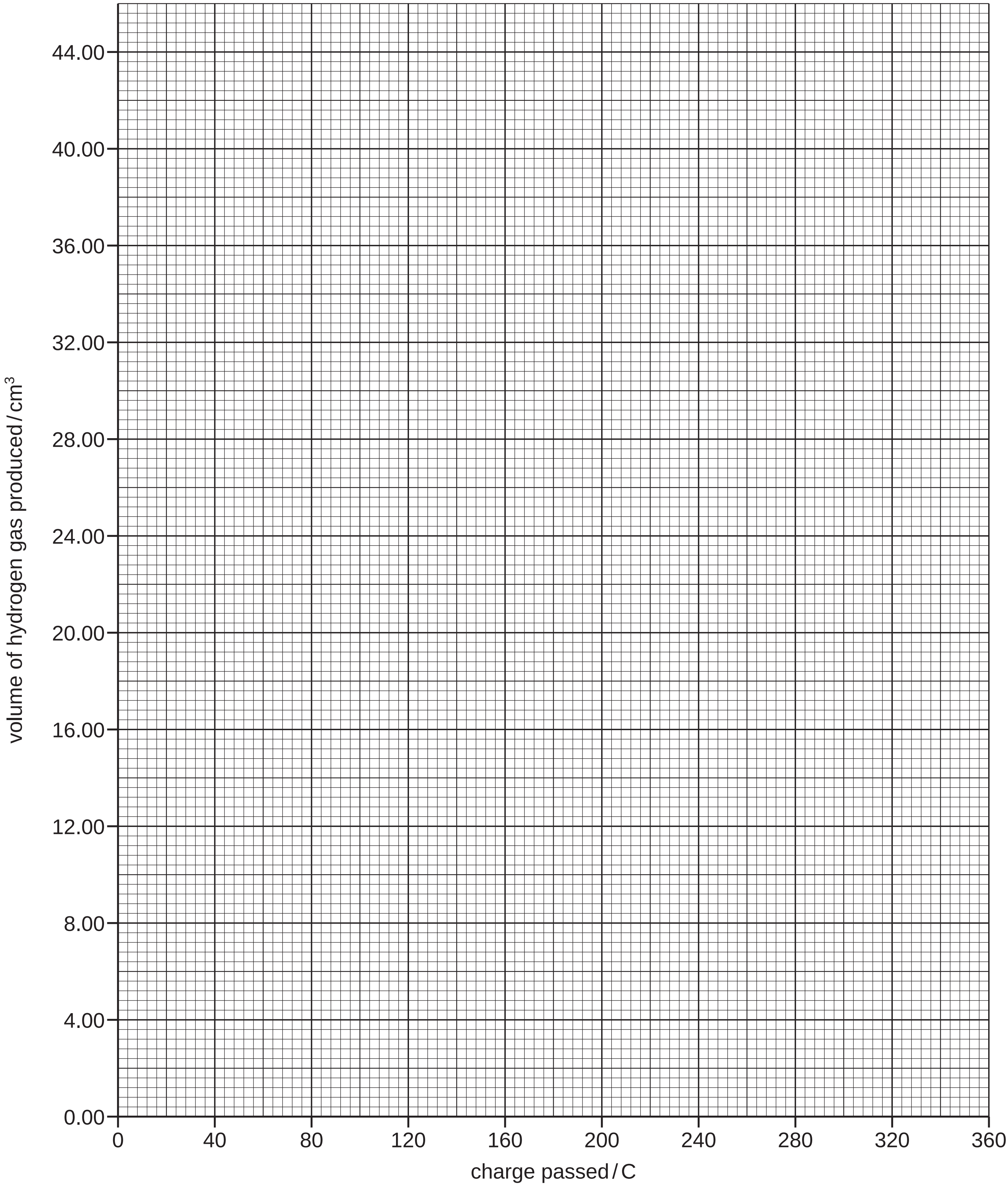
The current was kept constant at 0.80 A.

time / s	reading on burette **1** / cm^3	volume of hydrogen gas produced / cm^3	charge passed / C
0	46.20	0.00	
50	41.20		
100	36.20		
150	31.45		
200	25.80		
250	20.80		
300	16.40		
350	11.45		
400	6.80		
450	1.50		

[2]

(b) Plot a graph on the grid to show the relationship between volume of hydrogen gas produced and charge passed.

Use a cross (×) to plot each data point. Draw the straight line of best fit.



[2]

(c) Do you think the results obtained in **(a)** are reliable? Explain your answer.

....

....

.... [1]

(d) **(i)** The gradient of the line of best fit gives the volume of hydrogen gas produced per coulomb.

Use the graph to determine the gradient of the line of best fit.

State the co-ordinates of both points you used in your calculation.

co-ordinates 1 .... co-ordinates 2 ....

gradient = ... $cm^3\,C^{-1}$
[2]

(ii) Calculate the number of moles of hydrogen gas produced per coulomb.

If you were unable to obtain an answer for **(d)(i)***, you may use the value 0.148 $cm^3\,C^{-1}$, but this is not the correct answer.*

[The molar volume of gas = 24.0 dm^3 at room temperature and pressure.]

.... $mol\,C^{-1}$ [1]

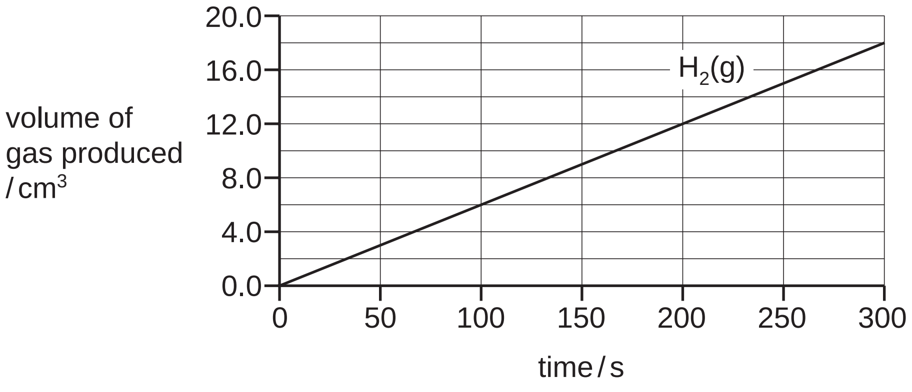
(iii) Use your answer to **(ii)** and the half-equation for the production of $H_2(g)$ to calculate a numerical value for the Faraday constant (the charge of 1 mole of electrons).

$$2H^+(aq) + 2e^- \rightarrow H_2(g)$$

.... $C\,mol^{-1}$ [1]

(e) **(i)** The graph below shows the relationship between volume of $H_2(g)$ produced at the cathode and time, in a similar experiment.

Draw a line on the graph to show the relationship between volume of $O_2(g)$ produced at the anode and time in this experiment.



[1]

(ii) Suggest why the volume of $O_2(g)$ measured in this experiment might be **less** than that shown by your drawn line.

Assume that no gas is lost from leaks.

....

.... [1]

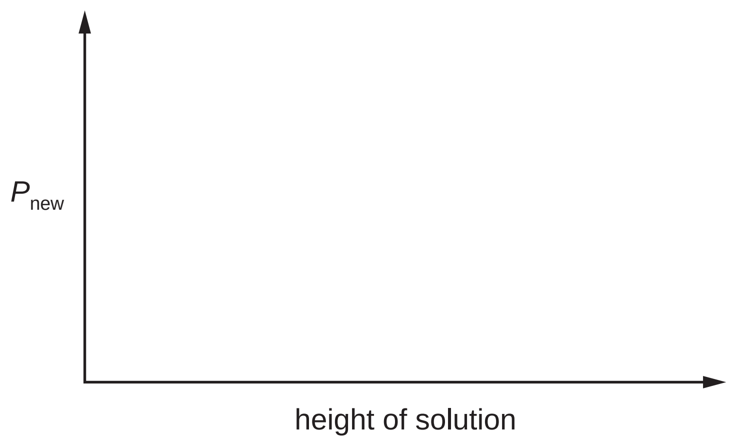
(f) In these experiments, the pressure of the gas inside the burette is assumed to be atmospheric pressure, P_{atm}.

However, the presence of water vapour and the mass of the solution in the burette change the pressure of the gas to P_{new}.

The expression below shows the relationship between P_{new} and P_{atm}.

$$P_{new} = P_{atm} - 2.81 - (9.81 \times \text{height of solution in burette})$$

(i) Use the expression to sketch a graph on the axes below to show the relationship between P_{new} and the height of solution in the burette.



[1]

(ii) State how P_{new} changes the value of the Faraday constant calculated at P_{atm} in **(d)(iii)**.

Explain your answer.

....

.... [1]

(g) A student's teacher suggested it would be cheaper to use copper rather than platinum electrodes in the electrolysis of dilute sulfuric acid.

half-equation	$E^{\ominus}$/V
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O(l)$	+1.23

Using the information in the table, suggest what effect, if any, the use of copper electrodes would have on the volume of gas produced at **each** electrode. Explain your answer.

cathode ....

....

....

anode ....

....

....

[3]

[Total: 16]