Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

7026641451

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2019**

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.

1 Yttrium barium copper oxide, $YBa_2Cu_3O_7$, is a crystalline compound.

You are to design an experiment in which $YBa_2Cu_3O_7$ is first synthesised and then analysed by titration.

(a) $YBa_2Cu_3O_7$ can be synthesised by reacting Y_2O_3, $BaCO_3$ and CuO using the following method.

- Place solid Y_2O_3, $BaCO_3$ and CuO together in a mortar and grind the mixture well with a pestle.
- Transfer the mixture to a porcelain crucible and place this in an oven set at 920 °C.
- Heat the mixture for 12 hours, then allow the crucible and its contents to cool slowly in the oven to below 100 °C before removing it.

The equation for the reaction is given.

$$Y_2O_3 + 4BaCO_3 + 6CuO + \tfrac{1}{2}O_2 \rightarrow 2YBa_2Cu_3O_7 + 4CO_2$$

(i) $YBa_2Cu_3O_7$ contains Y, Ba and Cu in the molar ratio of 1 : 2 : 3.

Calculate the minimum masses of $BaCO_3$ and CuO that are needed to react with 0.750 g of Y_2O_3, to give a Y : Ba : Cu ratio of 1 : 2 : 3.

[A_r: Y, 88.9; Ba, 137.3; Cu, 63.5; O, 16.0; C, 12.0]

mass of $BaCO_3$ = ... g

mass of CuO = ... g

[3]

(ii) State what should be done once the solid product has cooled to ensure that the highest possible yield of $YBa_2Cu_3O_7$ has been produced.

....

....

....

.... [1]

$YBa_2Cu_3O_7$ contains some copper ions in the unusual +3 oxidation state.

The proportion of Cu^{3+} in $YBa_2Cu_3O_7$ can be determined by titration.

- **Step 1**
  A sample of $YBa_2Cu_3O_7$ is reacted with an excess of concentrated aqueous HBr. Cu^{3+} ions are reduced to Cu^{2+} ions and Br_3^- ions are formed.

$$2Cu^{3+}(s) + 3Br^-(aq) \rightarrow 2Cu^{2+}(aq) + Br_3^-(aq)$$

- **Step 2**
  A solution of 1.0 mol dm^{-3} sodium citrate is added to the mixture from **Step 1**. The resulting mixture is then neutralised with a minimum volume of concentrated NH_3(aq).

- **Step 3**
  Excess I^- is added which reacts with Br_3^- to form I_2.

$$Br_3^-(aq) + 2I^-(aq) \rightarrow 3Br^-(aq) + I_2(aq)$$

- **Step 4**
  The I_2 is titrated with a standard solution of $S_2O_3^{2-}$ and starch solution as an indicator.

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

The concentration of I_2(aq) can therefore be determined and hence the concentration of Br_3^-(aq). From this the amount of Cu^{3+}(s) can be determined.

(b) The table gives some electrochemical data.

reduction process	$E^\ominus$/V
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54
$Cu^{2+} + I^- + e^- \rightleftharpoons CuI$	+0.86
$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1.23

Use these data and the information given above to answer the following questions.

(i) The citrate anion forms an insoluble complex with Cu^{2+} and so removes Cu^{2+} from solution.

Explain why this is necessary.

....

....

.... [1]

(ii) Explain why it is necessary to neutralise the mixture in **Step 2**.

....

.... [1]

(iii) When starch indicator is added in **Step 4**, the mixture turns blue-black due to the presence of I_2(aq). The end-point of the titration with $S_2O_3^{2-}$(aq) is a colourless solution.

The number of moles of $S_2O_3^{2-}$(aq) needed for complete reaction with I_2(aq) can be calculated from the mean titre value. Hence the moles of I_2(aq) can be determined.

State the expression for the moles of Cu^{3+} in the sample of $YBa_2Cu_3O_7$. Use A to represent the number of moles of I_2(aq) in **Step 4**.

moles Cu^{3+} = ... mol [1]

(c) (i) Calculate the mass of hydrated sodium citrate, $Na_3C_6H_5O_7$•$2H_2O$, that would be required for the preparation of 250.0 cm^3 of a solution of 1.0 mol dm^{-3} citrate ions, $C_6H_5O_7^{3-}$.

[M_r: $Na_3C_6H_5O_7$•$2H_2O$, 294.0]

mass of $Na_3C_6H_5O_7$•$2H_2O$ = ... g [1]

(ii) A student places the mass of $Na_3C_6H_5O_7$•$2H_2O$ calculated in **(c)(i)** into a beaker.

Describe how the student can prepare exactly 250.0 cm^3 of a solution of 1.0 mol dm^{-3} citrate ions from the sample in the beaker.

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

....

....

....

....

.... [3]

(d) A different student records the following titration data in **Step 4**.

experiment	rough	1	2
final reading / cm^3	21.20	24.60	47.75
initial reading / cm^3	0.00	3.10	25.30
titre / cm^3	21.20	21.50	22.45

Identify the problem with the student's titration method **and** suggest how it could be improved.

....

....

....

.... [2]

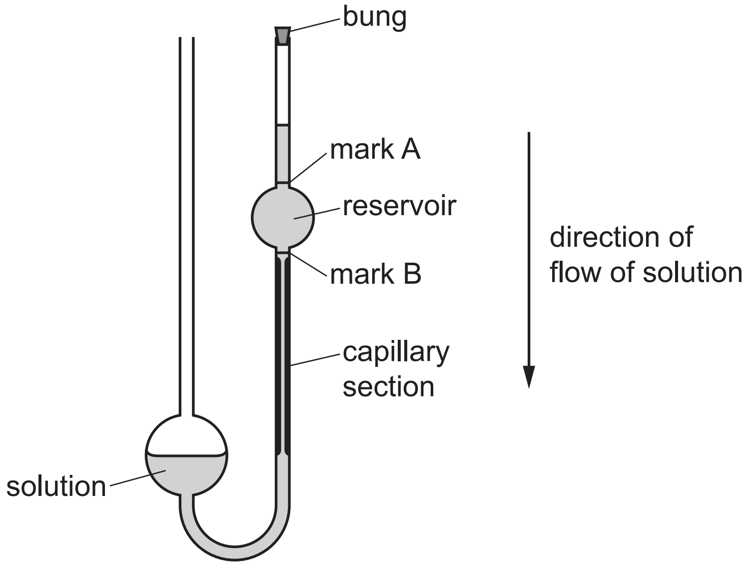
[Total: 13]

2 The viscosity of a substance is a measure of how quickly the substance flows when it is subjected to a force such as gravity. The viscosity of a liquid or solution is dependent on:

- size of molecules
- strength of intermolecular forces of attraction
- temperature.

It is possible to calculate the mean molecular mass (mean M_r) of a polymer in solution by measuring the viscosity of solutions of the polymer at different concentrations.

Measurements related to the viscosity of a solution can be made using a capillary viscometer, shown in the diagram.



- The apparatus is set up as shown.
- The bung is removed and the solution falls through the capillary section.
- The time taken for the top of the solution to pass between the two marks at the top (A) and bottom (B) of the reservoir is recorded.
- This time taken is related to the viscosity of the solution.

A student plans an experiment to calculate the mean M_r of molecules of poly(phenylethene). The student plans to make solutions of different concentrations of poly(phenylethene) dissolved in methylbenzene, $C_6H_5CH_3$, an organic solvent.

(a) Before the experiment, a mixture of concentrated nitric acid and concentrated hydrochloric acid is passed through the capillary viscometer. The capillary viscometer is then rinsed, first with water, and then with propanone.

Suggest why the capillary viscometer is rinsed with water and then with propanone.

rinse with water ....

....

rinse with propanone ....

....

[2]

Question 2 continues on the next page.

(b) A constant, η, related to the viscosity of a solution can be found by plotting a graph of $\left(\frac{1}{c}\right)\log\left(\frac{t}{t_0}\right)$ on the vertical axis against c on the horizontal axis.

c = concentration of poly(phenylethene) in $C_6H_5CH_3$ (in $g\,dm^{-3}$)
t = time taken for the solution to pass between marks A and B (in s)
t_0 = time taken for pure $C_6H_5CH_3$ to pass between marks A and B (in s)

The results of a series of experiments using different concentrations of poly(phenylethene) in $C_6H_5CH_3$ are shown. The values of $\frac{t}{t_0}$ have been calculated for you.

Process the results to complete the table.

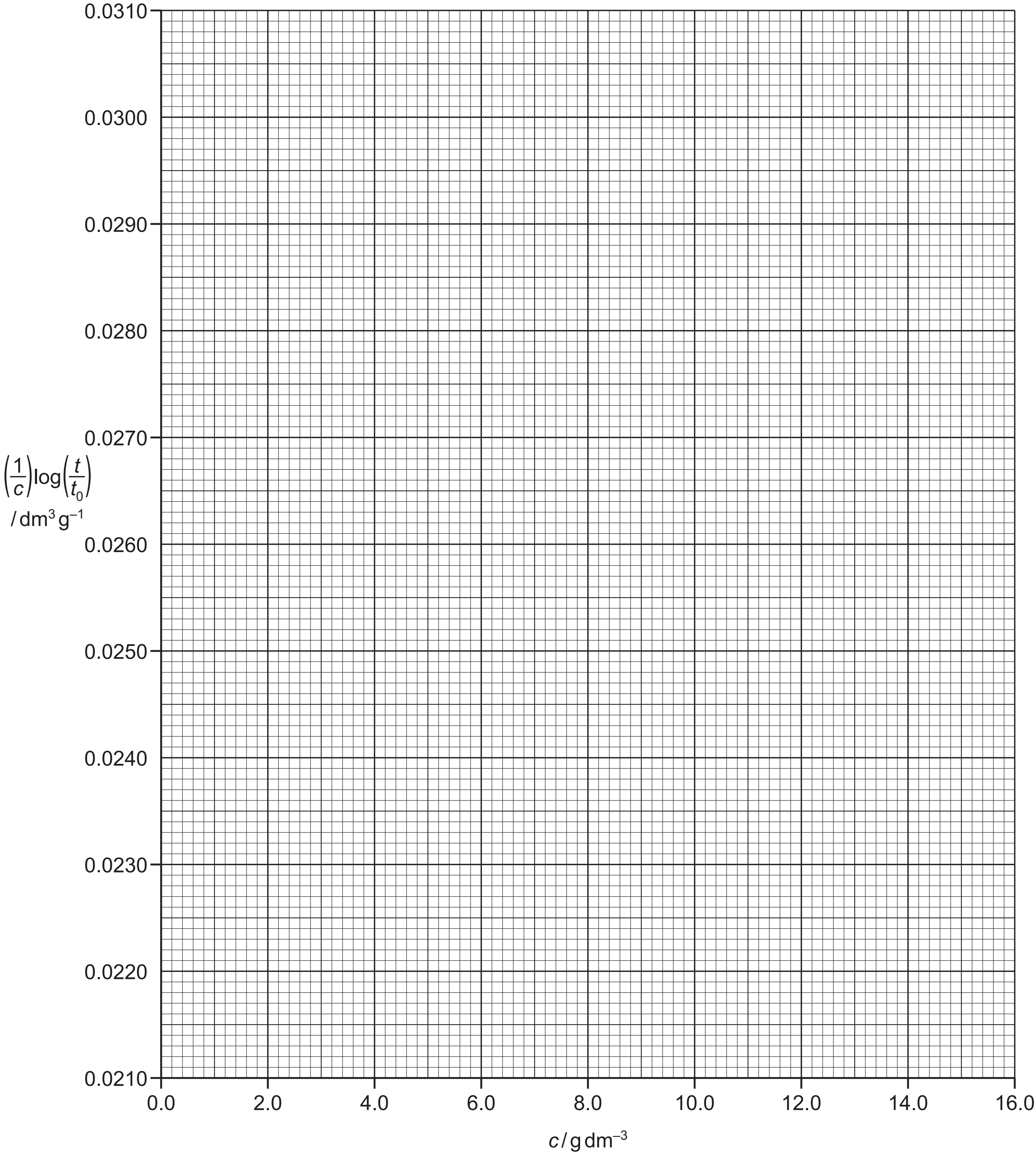
Record all your data to **three** significant figures.

concentration of poly(phenylethene), c / $g\,dm^{-3}$	$\frac{1}{c}$ / $dm^3\,g^{-1}$	time taken, t / s	$\frac{t}{t_0}$	$\log\left(\frac{t}{t_0}\right)$	$\left(\frac{1}{c}\right)\log\left(\frac{t}{t_0}\right)$ / $dm^3\,g^{-1}$
16.0		176	2.26		
14.0		164	2.10		
12.0		151	1.94		
10.0		138	1.77		
8.0		125	1.60		
6.0		113	1.45		
4.0		102	1.31		
2.0		89	1.14		

[3]

(c) Plot a graph on the grid to show the relationship between $\left(\frac{1}{c}\right)\log\left(\frac{t}{t_0}\right)$ and c.

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



[2]

(d) **(i)** Capillary viscometer measurements are usually made at 25 °C.

Predict the effect on the time taken for the solution to fall between marks A and B if a solution of temperature 18 °C is tested in the viscometer.

Explain your answer.

....

....

....

.... [2]

(ii) Suggest how a student could ensure that a measurement is made at 25 °C.

....

.... [1]

(e) The data you have plotted shows an anomaly that comes from the results obtained.

Circle the anomalous point on the graph.

Suggest a reason for this anomaly. Assume that for this result, the concentration of the solution was correct.

....

....

.... [1]

(f) The *y*-axis intercept on the graph in **(c)** is equal to $\frac{\eta}{2.30}$, where η is a constant for poly(phenylethene) at 25 °C.

(i) Use the graph you plotted in **(c)** to find a value for η.

η = ... $dm^3 g^{-1}$ [1]

The relationship between η and the mean M_r is shown.
(*K* and *a* have specific values for solutions of poly(phenylethene).)

$$\eta = K \times (\text{mean } M_r)^a$$

For a solution of poly(phenylethene) dissolved in $C_6H_5CH_3$ the relationship can be expressed as shown.

$$\log(\text{mean } M_r) = 1.59 \log \eta + 7.03$$

(ii) Use your value of η calculated in **(f)(i)** to calculate a value for the mean M_r of poly(phenylethene) in this experiment.

mean M_r = ...
[2]

(iii) Poly(phenylethene) forms when molecules of phenylethene, $CH_2CHC_6H_5$, undergo addition polymerisation.

$$x\,CH_2CHC_6H_5 \rightarrow (CH_2CHC_6H_5)_x$$

Use the value of mean M_r you calculated in **(f)(ii)** to calculate a value for *x*, the number of repeat units in the polymer.

Your answer should give the nearest whole-number value of *x*.

If you were unable to calculate a value in **(f)(ii)**, then you may use mean $M_r = 1.56 \times 10^5$, but this may not be the correct answer.

[A_r: C, 12.0; H, 1.0]

x = ...
[1]

(g) In the equation, $\eta = K \times (\text{mean } M_r)^a$, *a* depends on the strength of the intermolecular forces between the solvent and the solute.

The value of *a* increases as the intermolecular forces between solvent and solute increase.

Predict how the value of *a* for poly(ethenol) dissolved in water differs from *a* for poly(phenylethene) dissolved in $C_6H_5CH_3$.

Explain your answer.

....

....

....

.... [2]

[Total: 17]