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9701/51

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.

This document consists of **12** printed pages.



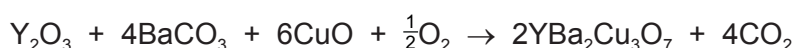
- 1 Yttrium barium copper oxide, $\text{YBa}_2\text{Cu}_3\text{O}_7$, is a crystalline compound.

You are to design an experiment in which $\text{YBa}_2\text{Cu}_3\text{O}_7$ is first synthesised and then analysed by titration.

- (a) $\text{YBa}_2\text{Cu}_3\text{O}_7$ 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.



- (i) $\text{YBa}_2\text{Cu}_3\text{O}_7$ 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 $\text{YBa}_2\text{Cu}_3\text{O}_7$ has been produced.

.....

.....

.....

..... [1]

YBa₂Cu₃O₇ contains some copper ions in the unusual +3 oxidation state.

The proportion of Cu³⁺ in YBa₂Cu₃O₇ can be determined by titration.

• **Step 1**

A sample of YBa₂Cu₃O₇ is reacted with an excess of concentrated aqueous HBr. Cu³⁺ ions are reduced to Cu²⁺ ions and Br₃⁻ ions are formed.

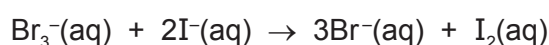


• **Step 2**

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 NH₃(aq).

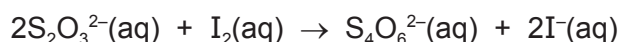
• **Step 3**

Excess I⁻ is added which reacts with Br₃⁻ to form I₂.



• **Step 4**

The I₂ is titrated with a standard solution of S₂O₃²⁻ and starch solution as an indicator.



The concentration of I₂(aq) can therefore be determined and hence the concentration of Br₃⁻(aq). From this the amount of Cu³⁺(s) can be determined.

(b) The table gives some electrochemical data.

reduction process	E°/V
$\text{I}_2 + 2\text{e}^{-} \rightleftharpoons 2\text{I}^{-}$	+0.54
$\text{Cu}^{2+} + \text{I}^{-} + \text{e}^{-} \rightleftharpoons \text{CuI}$	+0.86
$\text{O}_2 + 4\text{H}^{+} + 4\text{e}^{-} \rightleftharpoons 2\text{H}_2\text{O}$	+1.23

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

(i) The citrate anion forms an insoluble complex with Cu²⁺ and so removes Cu²⁺ 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, $Na_3C_6H_5O_7 \cdot 2H_2O$, 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 : $Na_3C_6H_5O_7 \cdot 2H_2O$, 294.0]

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

- (ii) A student places the mass of $Na_3C_6H_5O_7 \cdot 2H_2O$ 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]

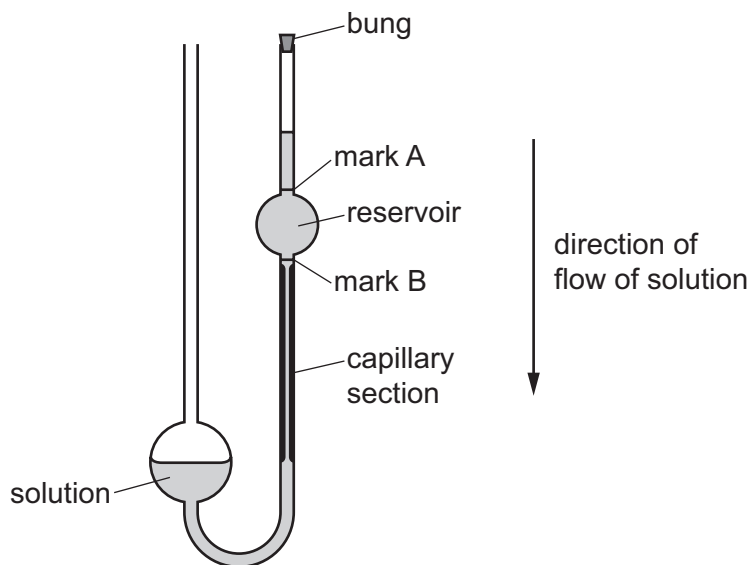
[Total: 13]

- 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 $\text{C}_6\text{H}_5\text{CH}_3$ (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 $\text{C}_6\text{H}_5\text{CH}_3$ to pass between marks A and B (in s)

The results of a series of experiments using different concentrations of poly(phenylethene) in $\text{C}_6\text{H}_5\text{CH}_3$ are shown. The values of $\frac{t}{t_0}$ have been calculated for you.

Process the results to complete the table.

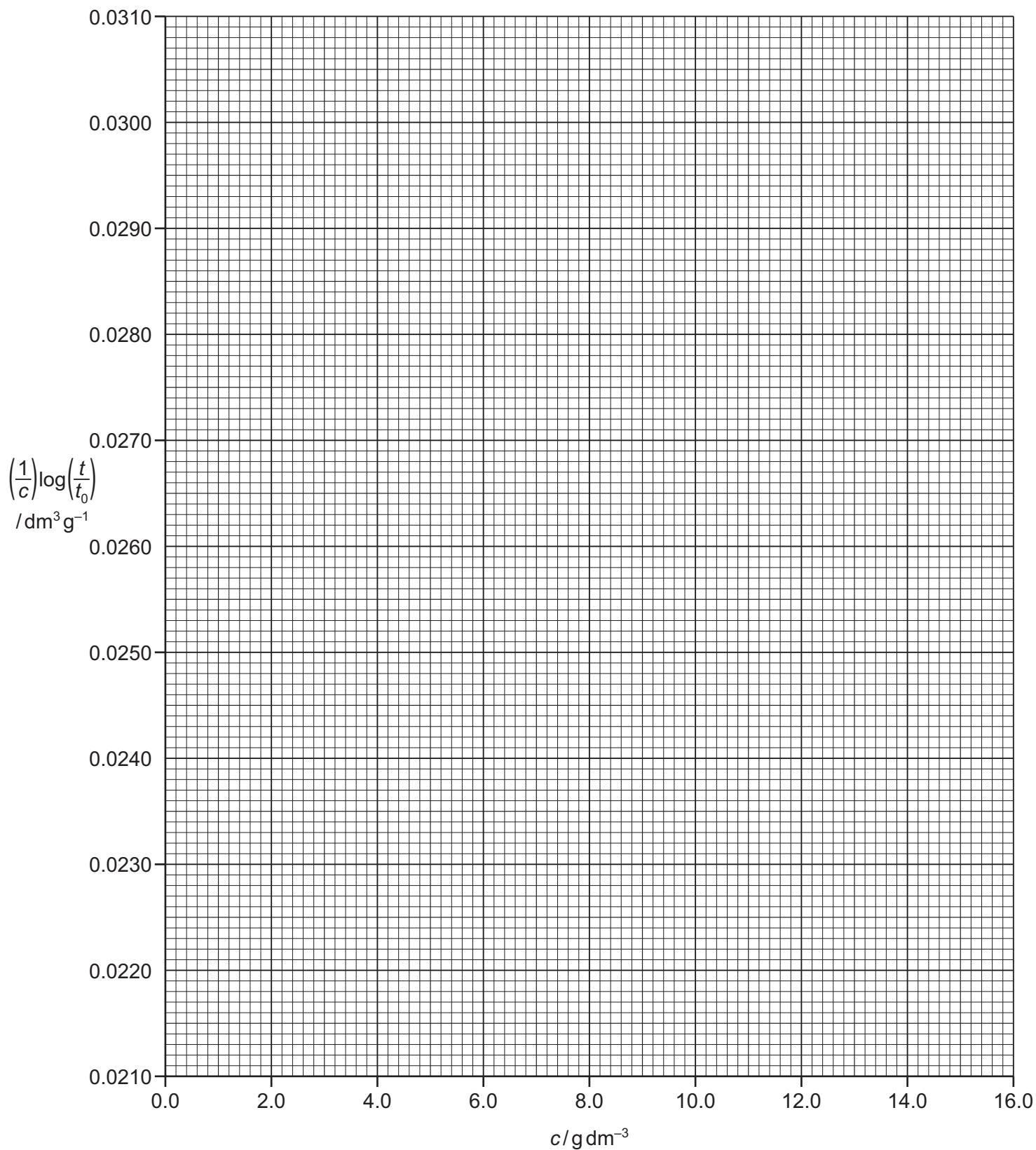
Record all your data to **three** significant figures.

concentration of poly(phenylethene), c $/\text{g dm}^{-3}$	$\frac{1}{c}$ $/\text{dm}^3\text{g}^{-1}$	time taken, t $/\text{s}$	$\frac{t}{t_0}$	$\log\left(\frac{t}{t_0}\right)$	$\left(\frac{1}{c}\right)\log\left(\frac{t}{t_0}\right)$ $/\text{dm}^3\text{g}^{-1}$
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 .

$$\eta = \dots\dots\dots \text{dm}^3\text{g}^{-1} \quad [1]$$

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

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

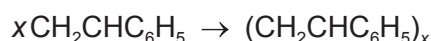
For a solution of poly(phenylethene) dissolved in $\text{C}_6\text{H}_5\text{CH}_3$ the relationship can be expressed as shown.

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

- (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.

$$\text{mean } M_r = \dots\dots\dots \quad [2]$$

- (iii) Poly(phenylethene) forms when molecules of phenylethene, $\text{CH}_2\text{CHC}_6\text{H}_5$, undergo addition polymerisation.



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]

$$x = \dots\dots\dots \quad [1]$$

- (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(ethanol) dissolved in water differs from a for poly(phenylethene) dissolved in $\text{C}_6\text{H}_5\text{CH}_3$.

Explain your answer.

.....

.....

.....

..... [2]

[Total: 17]

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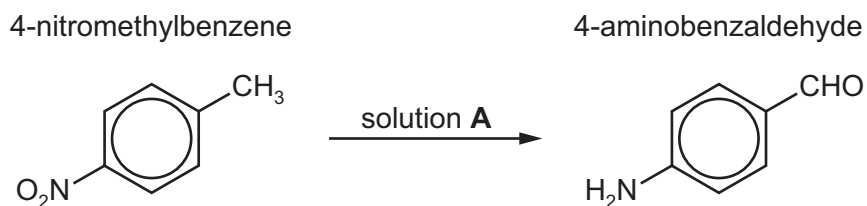
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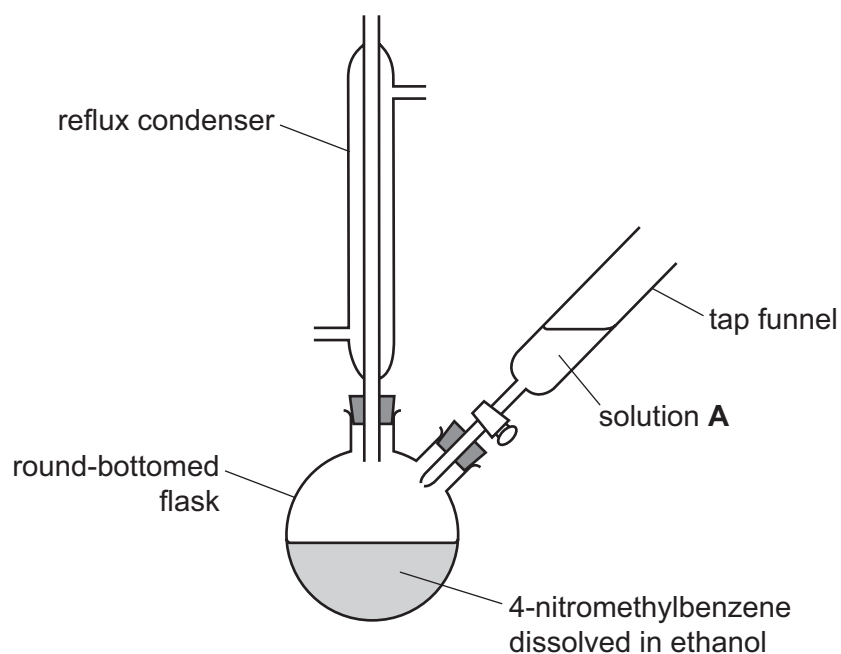


- 1 Many organic reactions performed in the laboratory require heating under reflux.

4-nitromethylbenzene can be converted directly to 4-aminobenzaldehyde by heating it under reflux with an excess of solution **A**. Solution **A** is an aqueous alkaline mixture of $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ and S_8 . Ethanol is used as a solvent for the reaction.



The apparatus for this reaction is shown in the diagram.



- (a) (i) Show, using a labelled arrow, where the cooling water enters the reflux condenser. [1]

- (ii) After the complete addition of solution **A** to the solution in the round-bottomed flask, a vigorous exothermic reaction takes place.

What should be done to control the vigorous exothermic reaction during the addition of solution **A**?

.....
..... [1]

- (iii) The mixture is heated to increase the rate of reaction. This is carried out under reflux.

Other than to increase the rate of reaction, explain why a reflux process is used for heating the mixture.

.....
..... [1]

- (iv) A student suggests that placing a bung in the top of the condenser would improve the experiment.

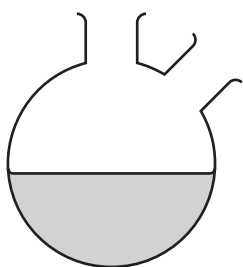
Comment on whether the student is correct. Explain your answer.

.....
.....
..... [1]

- (b) Once the reaction is complete, the round-bottomed flask is removed from the set-up on page 2 and included in a new set-up for distillation.

The distillation process separates the substances in the mixture in the flask.

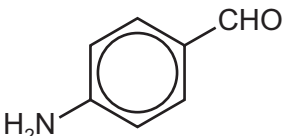
- (i) Complete and label the diagram to show how the apparatus could be set up for distillation.



[2]

- (ii) The mixture in the round-bottomed flask is heated until all of the first substance distils off. The heating is then stopped. After distillation a hot solution remains in the round-bottomed flask.

The table shows some data relevant to the experiment.

substance	melting point/ $^{\circ}\text{C}$	boiling point/ $^{\circ}\text{C}$
	72	138
H_2O	0	100
$\text{CH}_3\text{CH}_2\text{OH}$	-114	78

Use the data to identify the liquid that is first distilled off.
Explain your answer.

.....
..... [1]

- (iii) 4-aminobenzaldehyde is soluble in hot water, but not in cold water.

Starting with the hot solution in the round-bottomed flask, suggest how pure crystals of 4-aminobenzaldehyde can be obtained.

.....

 [2]

- (c) Under acidic conditions, 4-aminobenzaldehyde (C_7H_7NO) forms a solid compound with molecular formula $C_{14}H_{12}N_2O$.



A student carries out two experiments according to the method on page 2 to make C_7H_7NO .

In Experiment 1, the student obtains 6.00 g of solid.

In Experiment 2, the student uses the same method as in Experiment 1 but adds acid to neutralise the alkali in the mixture in the flask after heating under reflux.

The same quantities of reagents are used in Experiment 1 and Experiment 2.

Suggest how the mass of solid obtained in Experiment 2 compares to that of Experiment 1.

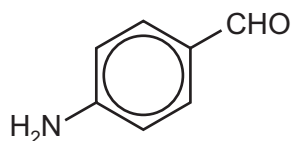
Explain your answer.

.....

 [2]

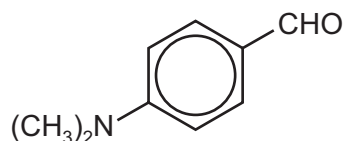
- (d) 4-aminobenzaldehyde can be reacted with a halogenoalkane to form 4-(dimethylamino)benzaldehyde, compound **D**.

4-aminobenzaldehyde



halogenoalkane

compound **D**



Some data is given that is relevant to this reaction.

halogenoalkane	boiling point / °C	carbon-halogen bond energy / kJ mol ⁻¹
CH ₃ Cl	-97	340
CH ₃ Br	4	280
CH ₃ I	43	240

Give **two** reasons why CH₃I is the preferred halogenoalkane in the conversion of 4-aminobenzaldehyde to compound **D**.

1

.....

2

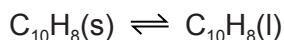
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[2]

[Total: 13]

- 2 Naphthalene, $C_{10}H_8$, is an aromatic organic compound that is a solid at room temperature and pressure.

The enthalpy change of fusion, ΔH_{fusion} , of naphthalene is the enthalpy change that occurs when naphthalene melts. It cannot be directly measured.



The melting point of naphthalene depends on its purity. When other compounds dissolve in liquid naphthalene its melting point is lowered.

Diphenylamine, $(C_6H_5)_2NH$, dissolves in liquid naphthalene. By varying the amount of diphenylamine and measuring the melting points of the different mixtures, the enthalpy change of fusion of naphthalene can be calculated.

- (a) The equation that links the melting point of a naphthalene-diphenylamine mixture with its enthalpy change of fusion, ΔH_{fusion} , is shown.

$$\log Y = A - \frac{\Delta H_{\text{fusion}}}{2.30 \times RT_m}$$

Y = mole fraction of naphthalene

R = molar gas constant, $8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

T_m = melting point of naphthalene in K

A is a constant

- (i) A series of experiments is performed using the same amount, 0.100 mol, of naphthalene each time.

Calculate the mass of naphthalene, $C_{10}H_8$, that should be used for each of these experiments.

[A_r : C, 12.0; H, 1.0]

mass of naphthalene = ... g [1]

- (ii) The melting point and freezing point of a substance are the same. The melting point, T_m , of a substance can be found by recording the temperature at which the substance freezes, measured when crystals first start to appear on cooling.

The results of a series of experiments using 0.100 mol of naphthalene and different masses of diphenylamine are shown.

Process the results to complete the table.

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

The mole fraction of naphthalene, Y , is calculated as shown.

$$Y = \frac{n_N}{n_N + n_D}$$

n_N = amount in moles of naphthalene, $C_{10}H_8$, = 0.100

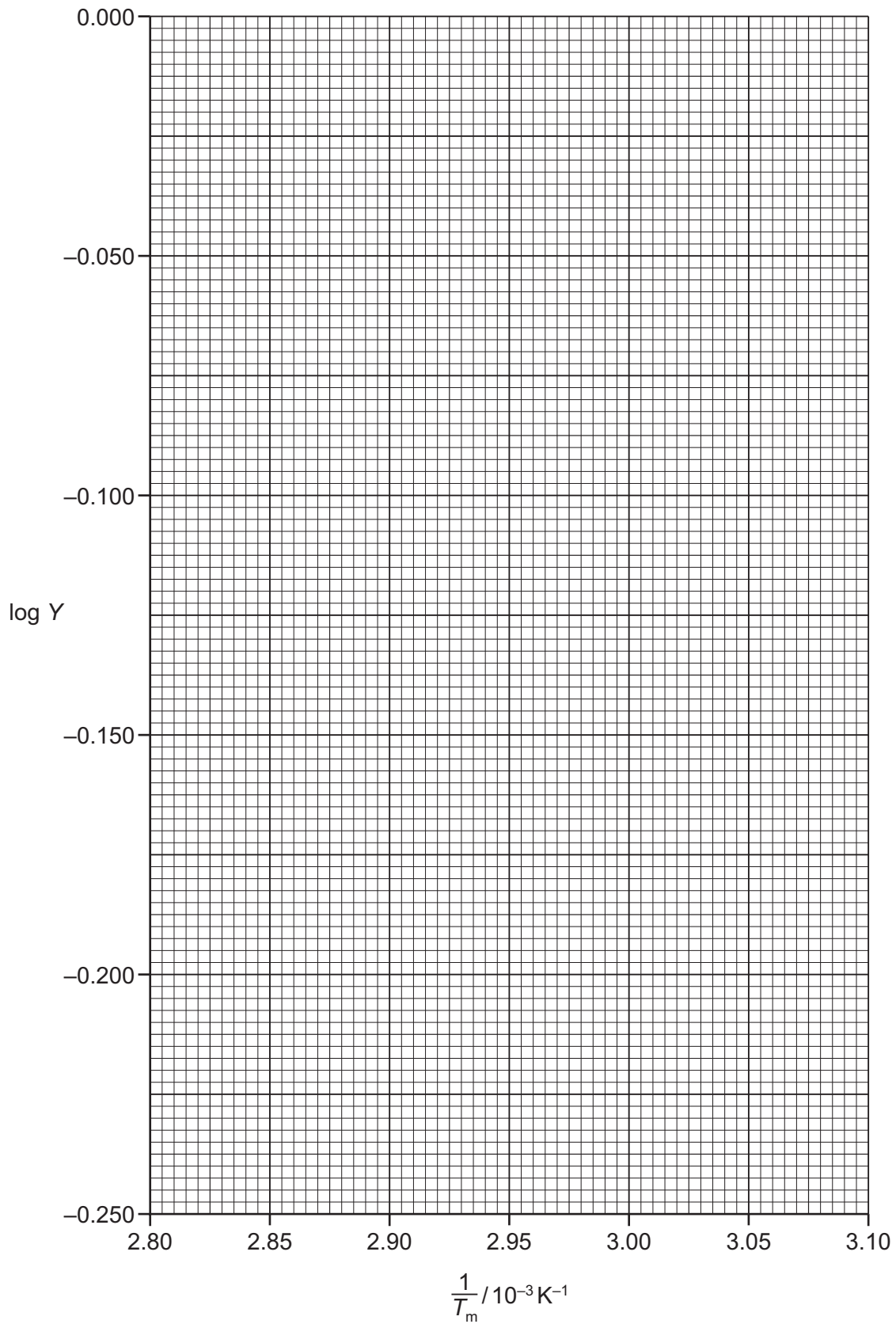
n_D = amount in moles of diphenylamine, $(C_6H_5)_2NH$

amount of $(C_6H_5)_2NH$, n_D /mol	mole fraction of $C_{10}H_8$, Y	temperature at which crystals appear, T_m /K	$\frac{1}{T_m}$ / $10^{-3} K^{-1}$	log Y
0.00	1.00	353	2.83	0.00
0.00888		349		
0.0178		345		
0.0266		341		
0.0355		338		
0.0444		334		
0.0533		331		
0.0621		329		
0.0769		325		

[3]

(b) Plot a graph on the grid to show the relationship between $\frac{1}{T_m}$ and $\log Y$.

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



[2]

- (c) (i) 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 = ... K
[2]

- (ii) Use your answer to (c)(i) to determine the value of the enthalpy change of fusion of naphthalene, ΔH_{fusion} , in kJ mol^{-1} .

$\Delta H_{\text{fusion}} = \dots\dots\dots \text{kJ mol}^{-1}$ [1]

- (d) (i) Do you consider the results obtained to be reliable? Explain your answer.

.....
.....
..... [1]

- (ii) Different literature values for the enthalpy change of fusion of naphthalene suggest that 10.00 g of naphthalene require between 1.45 kJ and 1.47 kJ to melt.

Use this information to calculate the range of ΔH_{fusion} values of naphthalene, C_{10}H_8 , given in literature.

Use your values to comment on the accuracy of the experimental procedure.

[A_r : C, 12.0; H, 1.0]

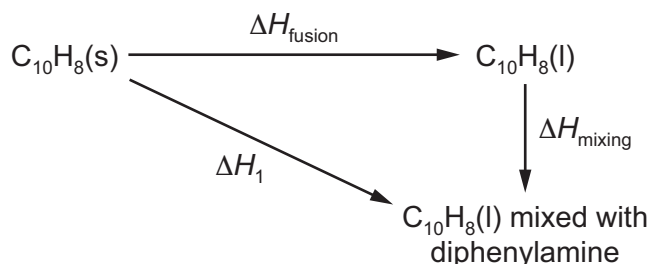
If you were not able to calculate ΔH_{fusion} in (c)(ii), you may use 18.4 kJ mol^{-1} , but this may not be the correct answer.

range kJ mol^{-1}

comment

..... [2]

- (e) The enthalpy change calculated in this reaction is actually ΔH_1 , shown in the Hess' cycle.



It is assumed that the enthalpy change when $\text{C}_{10}\text{H}_8(\text{l})$ and diphenylamine are mixed, ΔH_{mixing} , is zero, and therefore $\Delta H_1 = \Delta H_{\text{fusion}}$.

State how the value of ΔH_1 compares to the value of ΔH_{fusion} if the mixing of naphthalene and diphenylamine is endothermic.

Explain your answer.

.....

.....

.....

..... [2]

- (f) A student incorrectly uses a value for the M_r of diphenylamine that is too low. This produces incorrect values for the mole fraction, Y .
- (i) Predict the effect this will have on the calculated values of Y .

Explain your answer.

$$Y = \frac{n_N}{n_N + n_D}$$

n_N = amount in moles of naphthalene

n_D = amount in moles of diphenylamine

.....

.....

..... [1]

- (ii) The student uses the incorrectly calculated value of Y from (f)(i) in the determination of ΔH_{fusion} .

$$\log Y = A - \frac{\Delta H_{\text{fusion}}}{2.30 \times RT_m}$$

Predict how the student's calculated value of ΔH_{fusion} is different from the actual value.

Explain your answer.

.....

.....

..... [2]

[Total: 17]

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CANDIDATE
NAME

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CHEMISTRY

9701/53

Paper 5 Planning, Analysis and Evaluation

October/November 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

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This document consists of **12** printed pages.



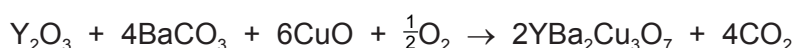
- 1 Yttrium barium copper oxide, $\text{YBa}_2\text{Cu}_3\text{O}_7$, is a crystalline compound.

You are to design an experiment in which $\text{YBa}_2\text{Cu}_3\text{O}_7$ is first synthesised and then analysed by titration.

- (a) $\text{YBa}_2\text{Cu}_3\text{O}_7$ 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.



- (i) $\text{YBa}_2\text{Cu}_3\text{O}_7$ 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 $\text{YBa}_2\text{Cu}_3\text{O}_7$ has been produced.

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..... [1]

YBa₂Cu₃O₇ contains some copper ions in the unusual +3 oxidation state.

The proportion of Cu³⁺ in YBa₂Cu₃O₇ can be determined by titration.

• **Step 1**

A sample of YBa₂Cu₃O₇ is reacted with an excess of concentrated aqueous HBr. Cu³⁺ ions are reduced to Cu²⁺ ions and Br₃⁻ ions are formed.

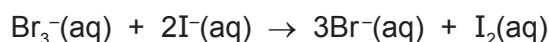


• **Step 2**

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 NH₃(aq).

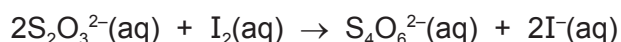
• **Step 3**

Excess I⁻ is added which reacts with Br₃⁻ to form I₂.



• **Step 4**

The I₂ is titrated with a standard solution of S₂O₃²⁻ and starch solution as an indicator.



The concentration of I₂(aq) can therefore be determined and hence the concentration of Br₃⁻(aq). From this the amount of Cu³⁺(s) can be determined.

(b) The table gives some electrochemical data.

reduction process	E°/V
$\text{I}_2 + 2\text{e}^{-} \rightleftharpoons 2\text{I}^{-}$	+0.54
$\text{Cu}^{2+} + \text{I}^{-} + \text{e}^{-} \rightleftharpoons \text{CuI}$	+0.86
$\text{O}_2 + 4\text{H}^{+} + 4\text{e}^{-} \rightleftharpoons 2\text{H}_2\text{O}$	+1.23

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

(i) The citrate anion forms an insoluble complex with Cu²⁺ and so removes Cu²⁺ 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 $\text{I}_2(\text{aq})$. The end-point of the titration with $\text{S}_2\text{O}_3^{2-}(\text{aq})$ is a colourless solution.

The number of moles of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ needed for complete reaction with $\text{I}_2(\text{aq})$ can be calculated from the mean titre value. Hence the moles of $\text{I}_2(\text{aq})$ can be determined.

State the expression for the moles of Cu^{3+} in the sample of $\text{YBa}_2\text{Cu}_3\text{O}_7$. Use A to represent the number of moles of $\text{I}_2(\text{aq})$ in **Step 4**.

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

- (c) (i) Calculate the mass of hydrated sodium citrate, $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 2\text{H}_2\text{O}$, that would be required for the preparation of 250.0 cm^3 of a solution of 1.0 mol dm^{-3} citrate ions, $\text{C}_6\text{H}_5\text{O}_7^{3-}$.

[M_r : $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 2\text{H}_2\text{O}$, 294.0]

mass of $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 2\text{H}_2\text{O}$ = ... g [1]

- (ii) A student places the mass of $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 2\text{H}_2\text{O}$ 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.

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..... [2]

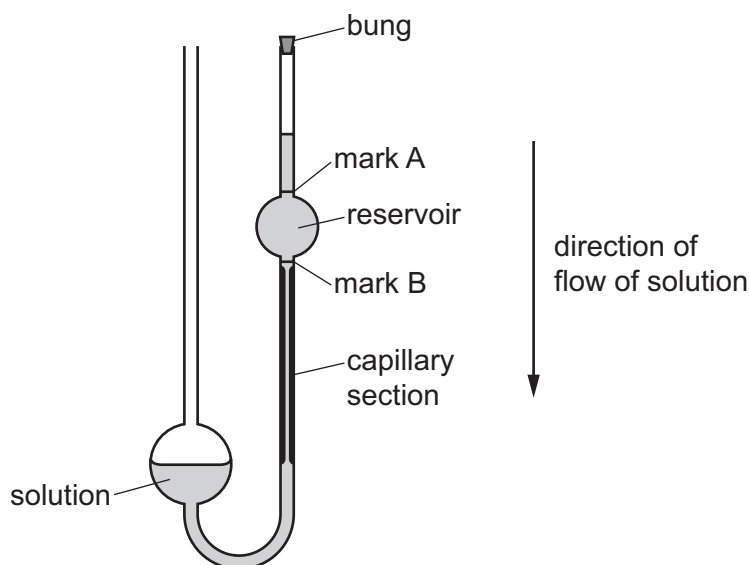
[Total: 13]

- 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 $\text{C}_6\text{H}_5\text{CH}_3$ (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 $\text{C}_6\text{H}_5\text{CH}_3$ to pass between marks A and B (in s)

The results of a series of experiments using different concentrations of poly(phenylethene) in $\text{C}_6\text{H}_5\text{CH}_3$ are shown. The values of $\frac{t}{t_0}$ have been calculated for you.

Process the results to complete the table.

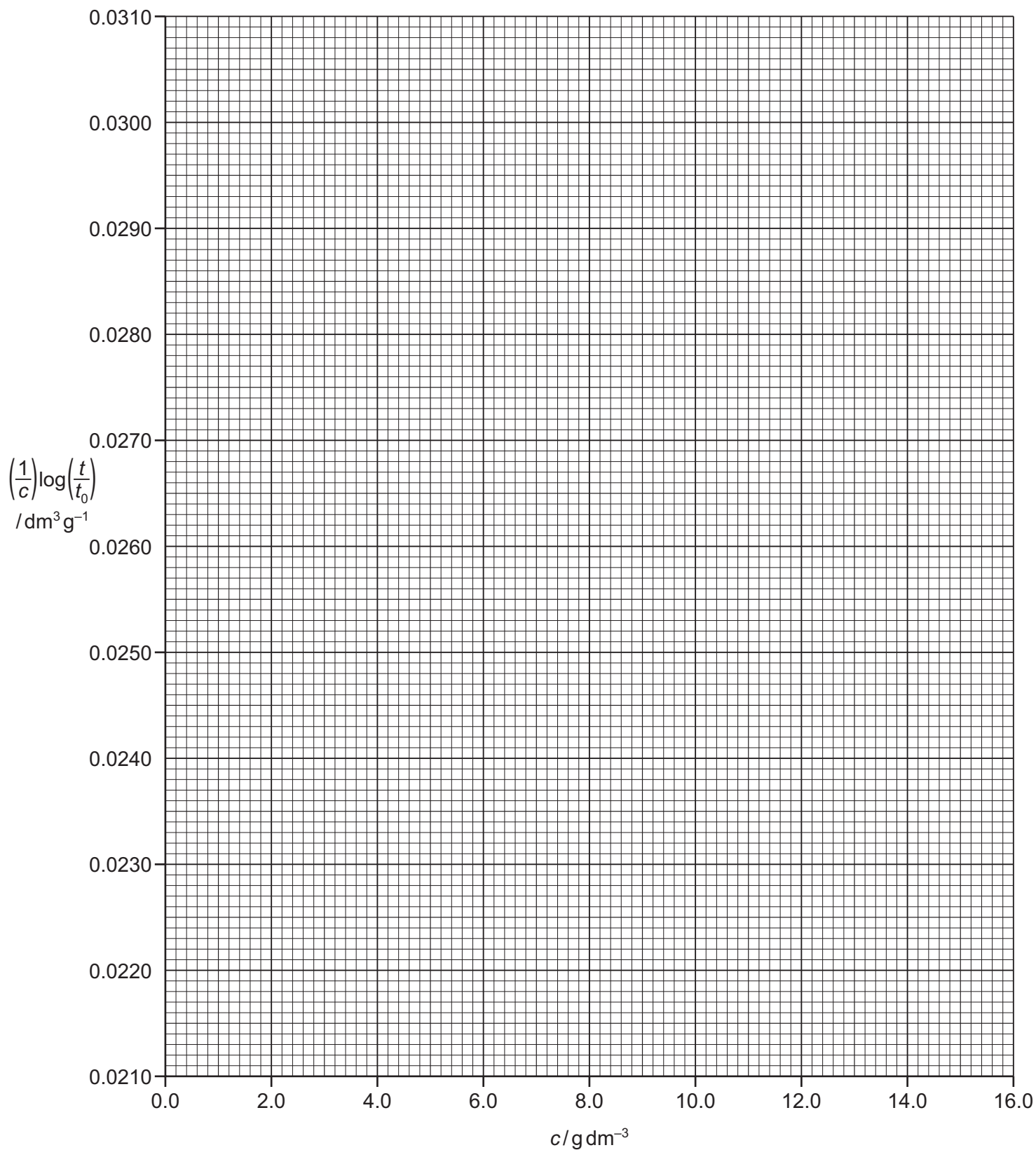
Record all your data to **three** significant figures.

concentration of poly(phenylethene), c / g dm^{-3}	$\frac{1}{c}$ / dm^3g^{-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^3g^{-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.

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..... [2]

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

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..... [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.

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..... [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 .

$$\eta = \dots\dots\dots \text{dm}^3\text{g}^{-1} \quad [1]$$

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

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

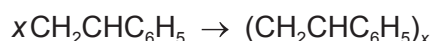
For a solution of poly(phenylethene) dissolved in $\text{C}_6\text{H}_5\text{CH}_3$ the relationship can be expressed as shown.

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

- (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.

$$\text{mean } M_r = \dots\dots\dots \quad [2]$$

- (iii) Poly(phenylethene) forms when molecules of phenylethene, $\text{CH}_2\text{CHC}_6\text{H}_5$, undergo addition polymerisation.



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]

$$x = \dots\dots\dots \quad [1]$$

- (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(ethanol) dissolved in water differs from a for poly(phenylethene) dissolved in $\text{C}_6\text{H}_5\text{CH}_3$.

Explain your answer.

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..... [2]

[Total: 17]

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