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CHEMISTRY

9701/51

Paper 5 Planning, Analysis and Evaluation

October/November 2015

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.

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This document consists of **9** printed pages and **3** blank pages.

- 1 It is possible to determine the relative molecular mass, M_r , of a small sample of a volatile liquid by measuring its mass and then heating to vaporise it to obtain its volume as a gas.

(a) Explain how the relative molecular mass can be determined in this way.

.....

.....

.....

..... [2]

(b) (i) The volume of the vaporised sample depends on its temperature and pressure.

In an experiment, a sample of volatile liquid of known mass was vaporised and its volume recorded. The pressure was correctly recorded as 101 kPa but the temperature was incorrectly recorded as 50 °C. The correct temperature was 60 °C.

By considering the effect of these different temperatures on the gas volume, explain how the value of the calculated M_r would be affected.

.....

.....

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..... [3]

(ii) The temperature was maintained at 60 °C but the pressure was increased to 110 kPa. Would this have given an answer that was nearer to the true value of the relative molecular mass? Explain your answer.

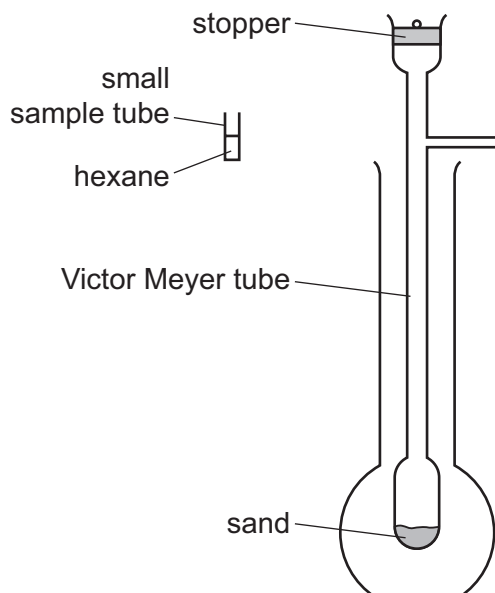
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..... [1]

In an experiment to determine the relative molecular mass of hexane, boiling point 69°C , a specialist piece of apparatus called a Victor Meyer tube can be used. This consists of a long tube with a bulb at the base in which a sample can be vaporised. The tube has a side arm to allow the escape of gas from within the tube. The tube is surrounded by another which can be used to heat the contents of the first tube.

A diagram of the apparatus is shown below.



A small sample tube containing the hexane is inserted at the top of the Victor Meyer tube. The sample tube is small enough to fit inside the Victor Meyer tube and falls freely onto the hot sand below. The sand will cushion its fall so that the sample tube does not break. The stopper is then quickly replaced at the top of the Victor Meyer tube. The hot sand causes the hexane to vaporise and expel air contained in the Victor Meyer tube.

(c) Complete the diagram above to show:

- how the apparatus should be heated,
- a connection to further apparatus which would allow the air expelled from the Victor Meyer tube when the sample of hexane is vaporised to be collected and measured.

[2]

(d) Suggest **one** hazard associated with the use of hexane.

.....
 [1]

- (e) (i) With the gas collection apparatus connected to the heated Victor Meyer tube, expelled air will be collected before the hexane is introduced. Explain why.

.....
.....
.....
..... [2]

- (ii) At which stage of the experimental procedure should the sample tube be dropped into the Victor Meyer tube?

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

- (f) State what measurements you would need to make in order to determine the relative molecular mass of hexane.

.....
.....
.....
.....
..... [3]

[Total: 15]

QUESTION 2 STARTS ON THE NEXT PAGE.

- 2 In an experiment, various masses of solid barium hydroxide are added to 60.0 cm^3 of a solution of hydrochloric acid contained in a polystyrene cup.

In each experiment a fresh sample of the acid is taken and its initial temperature is measured. After the barium hydroxide has been added, the acid is stirred and the maximum temperature reached is noted.

The results of each experiment are recorded in the table below.

- (a) Complete the table below to give the temperature rise obtained from each experiment to **one decimal place** and the amount of barium hydroxide used in mol to **three significant figures** in each case.

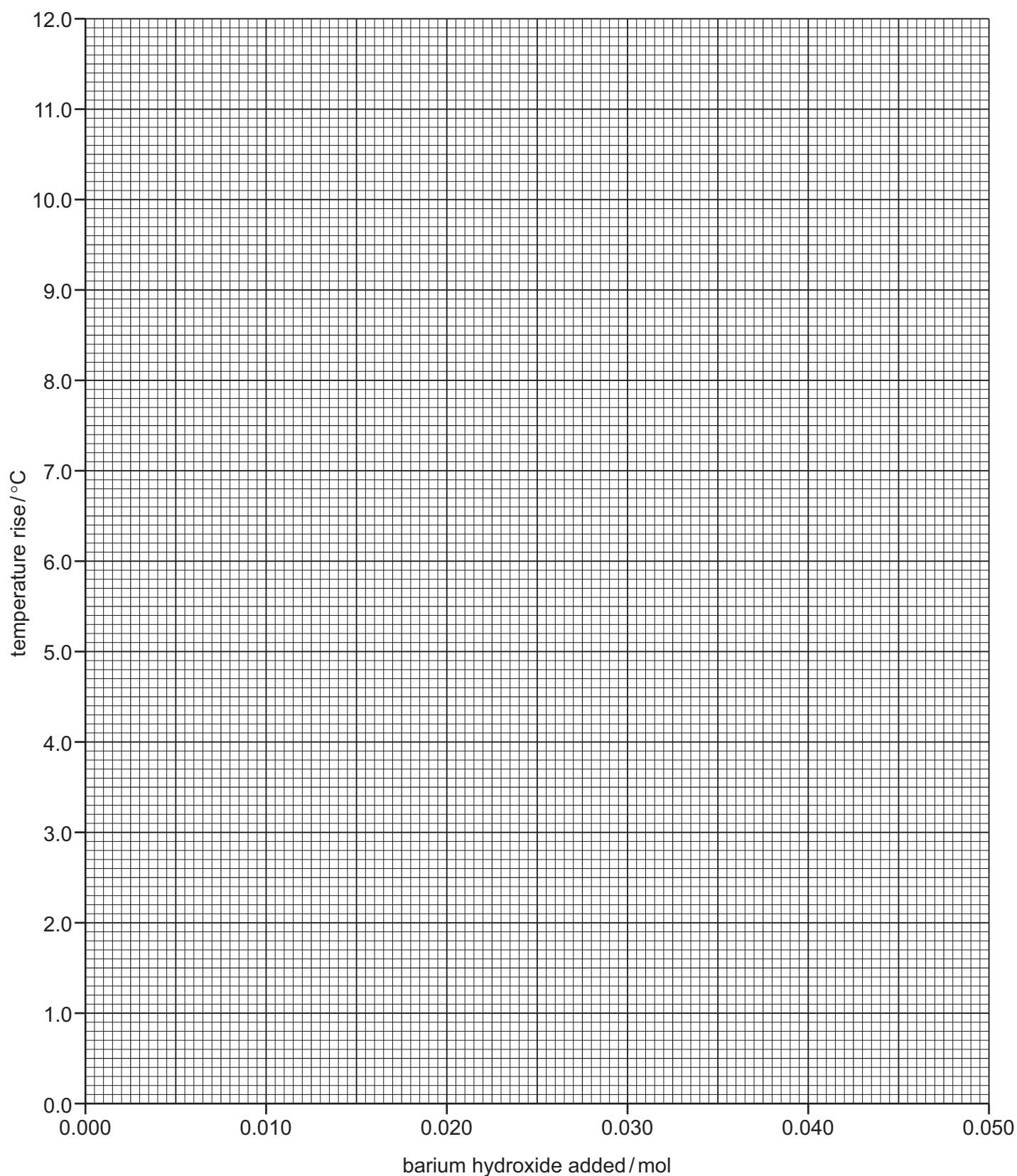
The mass of 1 mol of barium hydroxide is 171 g.

initial temperature of HCl/ $^{\circ}\text{C}$	mass of barium hydroxide added /g	maximum temperature reached/ $^{\circ}\text{C}$	temperature rise/ $^{\circ}\text{C}$	barium hydroxide added /mol
21.0	0.500	22.2		
20.6	1.00	23.0		
21.2	1.50	24.9		
21.8	2.00	26.5		
20.5	3.00	27.8		
21.4	4.00	31.1		
21.2	5.00	31.6		
21.0	6.00	31.4		
20.8	8.00	31.2		

[2]

- (b) (i) Using the grid on page 7, plot a graph to show how the temperature rise varies with the moles of barium hydroxide added.

[1]



- (ii) Draw **two** lines of best fit on your graph and state the value on the x-axis at the point of intersection of the two lines.

value on the x-axis at the point of intersection is

[2]

- (c) Use the value on the x-axis at the point of intersection to calculate the concentration of the hydrochloric acid in mol dm^{-3} .

[2]

- (d) Explain the variation in temperature that takes place when barium hydroxide is added to the hydrochloric acid.

.....

.....

.....

.....

.....

..... [2]

- (e) (i) When the experiment is done in the way described, the results are not very accurate.

Apart from limitations due to the accuracy of the measuring equipment, suggest why:

- all the temperature rises measured are less than theoretically should be expected,

.....

.....

- the temperature rises are more inaccurate as they approach their maximum value.

.....

.....

[2]

- (ii) What improvement would you make to achieve greater accuracy?

.....

.....

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- (f) In another experiment, 60.0 cm^3 of ethanoic acid is used instead of the 60.0 cm^3 of hydrochloric acid.

If the ethanoic acid has the same concentration as the hydrochloric acid, draw on your graph another pair of lines to show the results you would expect to obtain.

Explain your answer.

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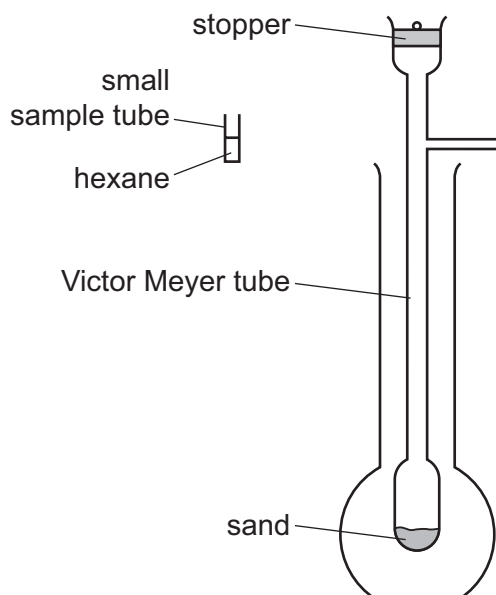
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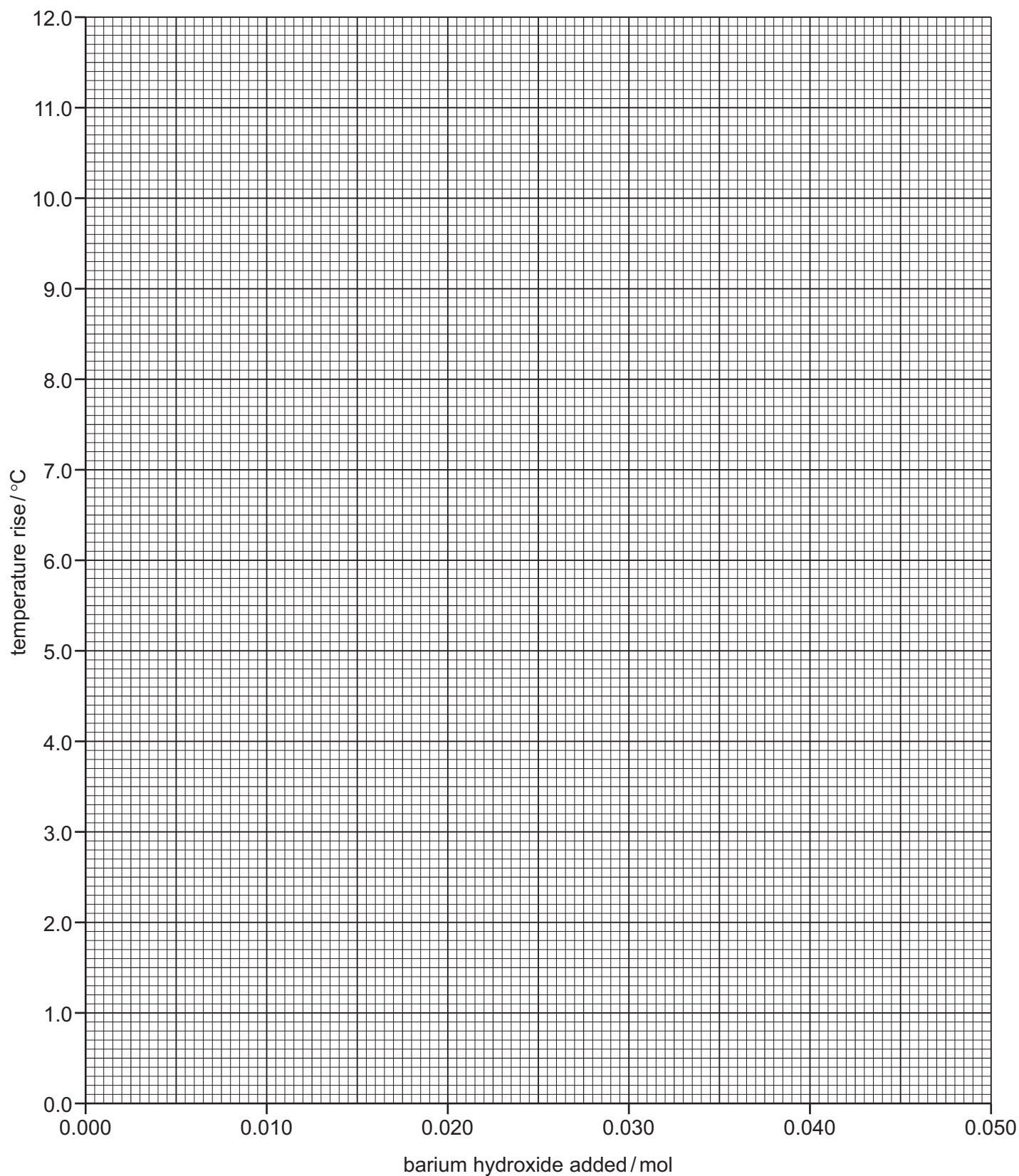
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[1]



- (ii) Draw **two** lines of best fit on your graph and state the value on the x-axis at the point of intersection of the two lines.

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1 The halogenoalkanes can react with hydroxide ions to form an alcohol and a halide ion.

(a) The rate at which the reaction occurs depends on which of the halogenoalkanes is chosen. The reaction is a nucleophilic attack by the hydroxide ion and the rate might depend on:

- the polarity of the carbon-halogen bond,
- the bond strength of the carbon-halogen bond.

For (i) and (ii), chlorobutane, bromobutane and iodobutane should be considered.

(i) If the rate of reaction was only controlled by the polarity of the carbon-halogen bond, the order of reactivity (most reactive to least reactive) would be

.....

Explain the variation in the polarity of the carbon-halogen bonds.

.....

.....

.....

[2]

(ii) If the rate of reaction was only controlled by the bond strength of the carbon-halogen bond, the order of reactivity (most reactive to least reactive) would be

.....

Explain the variation in the bond strength of the carbon-halogen bonds.

.....

.....

.....

[2]

- (b) An experiment can be carried out to compare the extent of the reaction between aqueous hydroxide ions and chlorobutane, bromobutane and iodobutane. Samples of the halogenoalkanes are reacted with sodium hydroxide for 2 minutes at 50 °C. After the reaction, addition of aqueous silver nitrate causes the formation of a silver halide precipitate.

Some hazards associated with the use of halogenoalkanes include:

- very hazardous in case of skin and particularly eye contact,
- very hazardous if inhaled or ingested,
- flammable.

To carry out this experiment, the following would be supplied.

- usual laboratory apparatus
- laboratory reagents including a suitable aqueous solution of sodium hydroxide and aqueous silver nitrate
- samples of each of the three liquid halogenoalkanes

- (i) Identify the independent variable and the dependent variable in this experiment.

independent variable

dependent variable

[1]

- (ii) The amount of each halogenoalkane liquid to use is most practically measured by its volume. Usually equal volumes of the three halogenoalkanes are used.

Explain why this is not ideal and what change should be made to obtain a more reliable comparison between the halogenoalkanes.

.....

.....

.....

..... [2]

(iii) Answer the following questions about the experiment.

- Having measured the quantity of halogenoalkanes, what must be ensured about the amount of sodium hydroxide used?

.....

.....

- How would the reaction tubes be heated and the experiment be started?

.....

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.....

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- What reagent could be added which would ensure that after 2 minutes the reaction was stopped?

.....

.....

- After the reaction has been stopped and aqueous silver nitrate added, the amount of precipitate formed could be determined by measuring its height.
Why is it necessary to leave the tubes for some time before making this measurement?

.....

.....

.....

[5]

(iv) Although the amount of silver halide formed can reasonably be obtained by measuring the height of the precipitate in the reaction tube, this is not very reliable.

Explain what should be done with the precipitate to obtain a more reliable measurement of the amount of silver halide produced.

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.....

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[2]

- (c) The use of halogenoalkanes is hazardous and both gloves and eye protection are necessary. State one other essential precaution which should be taken when carrying out the experiments.

.....

.....

.....

..... [1]

[Total: 15]

- 2 At 25 °C, dinitrogen tetroxide, $\text{N}_2\text{O}_4(\text{g})$, forms an equilibrium mixture with nitrogen dioxide, $\text{NO}_2(\text{g})$.



As $\text{N}_2\text{O}_4(\text{g})$ is colourless and $\text{NO}_2(\text{g})$ is brown, the composition of an equilibrium mixture can be determined by its colour.

- (a) Write an expression for the equilibrium constant, K_c , for this equilibrium.

[1]

- (b) In an experiment, quantities of N_2O_4 are left to reach an equilibrium which contains N_2O_4 and NO_2 . These are analysed to determine the concentrations of $\text{N}_2\text{O}_4(\text{g})$ and $\text{NO}_2(\text{g})$ that are present. The results are listed in the first two columns of the table below.

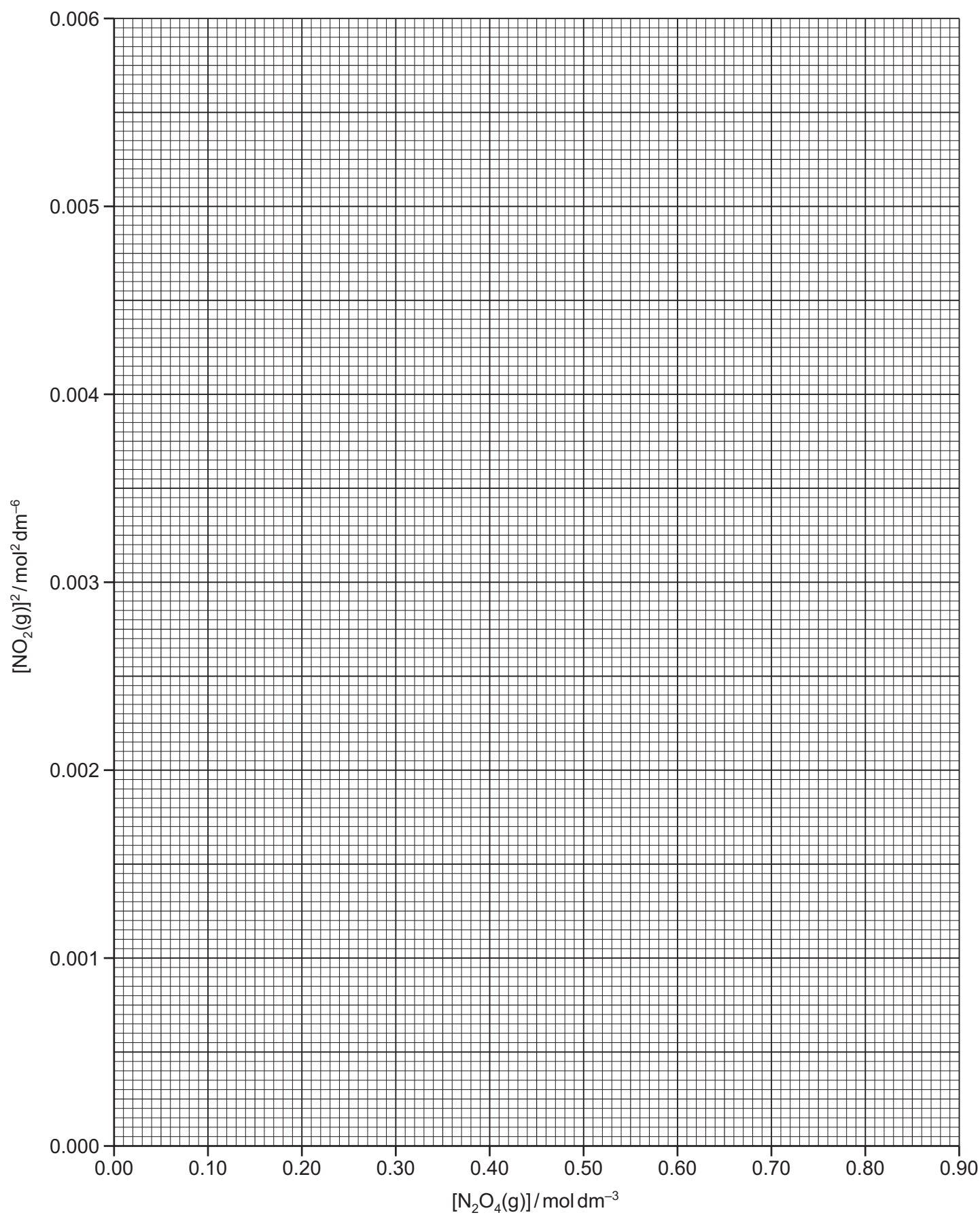
Complete the third column of the table to give the value of $[\text{NO}_2(\text{g})]^2$ for each of the results of the experiment. Values should be given to **three significant figures**.

$[\text{N}_2\text{O}_4(\text{g})]/\text{mol dm}^{-3}$	$[\text{NO}_2(\text{g})]/\text{mol dm}^{-3}$	$[\text{NO}_2(\text{g})]^2/\text{mol}^2 \text{ dm}^{-6}$
0.900	0.0729	
0.800	0.0687	
0.700	0.0643	
0.600	0.0595	
0.500	0.0548	
0.400	0.0486	
0.300	0.0390	
0.200	0.0344	
0.100	0.0243	

[2]

- (c) (i) The value of the equilibrium constant for $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ can be calculated from a graph of $[\text{N}_2\text{O}_4(\text{g})]$ against $[\text{NO}_2(\text{g})]^2$.

Use the grid on page 7 to plot this graph and draw a line of best fit through the plotted points.



[2]

- (ii) Choose two suitable sets of values from your graph and use them to calculate a value for the equilibrium constant, K_c . Give your answer to **three significant figures** and give its units.

co-ordinates of two points used

$K_c = \dots\dots\dots$ units [3]

- (d) Identify the result which is most anomalous and suggest a reason, other than a calculation error, why this may have occurred.

.....

 [2]

- (e) (i) On your graph, draw a line that would be obtained if the temperature of the equilibrium mixture was raised. [1]

- (ii) Explain the position of the line drawn in (i).

.....
 [1]

- (iii) What effect, if any, would the higher temperature have on the value of K_c ?

.....
 [1]

- (iv) How would your value for the equilibrium constant change if the pressure applied to the equilibrium mixture was increased?

..... [1]

- (f) In the experiments, the results have been obtained by starting with pure $\text{N}_2\text{O}_4(\text{g})$ and then letting the equilibrium with $\text{NO}_2(\text{g})$ form.

Calculate the starting concentration of pure $\text{N}_2\text{O}_4(\text{g})$ that would be required to produce the mixture of $0.900 \text{ mol dm}^{-3}$ of $\text{N}_2\text{O}_4(\text{g})$ and $0.0729 \text{ mol dm}^{-3}$ of $\text{NO}_2(\text{g})$ once equilibrium had been established.

[1]

[Total: 15]

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