UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **October/November 2013**

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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.

For Examiner's Use	
1	
2	
Total	

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

UNIVERSITY of CAMBRIDGE International Examinations

For Examiner's Use

1 Ammonium nitrate, NH_4NO_3, is soluble in water (approximately 2.5 mol / 100 g at 25 °C). The molar enthalpy of solution of a solid is defined as the enthalpy change when one mole of the solid is dissolved in water.

$$NH_4NO_3(s) \rightleftharpoons NH_4^+(aq) + NO_3^-(aq) \qquad \Delta H_{soln} = +26.5\,kJ\,mol^{-1}$$

(a) (i) Predict how the temperature of water, initially at 25 °C, would change as ammonium nitrate is dissolved. Explain this prediction in terms of lattice energy and the enthalpy of hydration of ions.

Prediction of the temperature change .....

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Explanation .....

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(ii) In the space below, sketch a graph to show your prediction of temperature change with concentration. Use two labelled axes and include an origin.

[4]

(b) If you were to carry out an experiment to investigate how the **temperature change** of the solution varies as the **concentration changes** name,

(i) the independent variable, ...

(ii) the dependent variable. .....

[1]

(c) You are to plan an experiment to determine as accurately as possible how the temperature change varies when different solutions are made, each with different concentrations of ammonium nitrate. You are reminded that the approximate solubility of ammonium nitrate is 2.5 mol / 100 g at 25 °C.

The following information gives some of the hazards associated with ammonium nitrate.

> **Ammonium nitrate** NH_4NO_3. Contact with combustible material may cause fire. Explosive when mixed with combustible material.
> **Do not allow the salt to become contaminated with organic matter and do not grind it.**
> Solutions should be diluted to less than 0.5 mol dm^{-3} for disposal.

You should use only standard apparatus found in a school or college laboratory. Draw a diagram of the apparatus and experimental set up you would use showing clearly the following:

(i) the apparatus used, such as the reaction vessel, and how the thermometer will be positioned in order to measure the temperature of the solution as accurately as possible,

(ii) how the apparatus will be insulated.

Label each piece of apparatus used, indicating its size or capacity and both the temperature range and the precision of the thermometer.

[3]

(d) Using the apparatus shown in **(c)** design an experiment to test your prediction in **(a)(ii)** of how the temperature change of the solution varies with solutions of different concentration.

In addition to the apparatus normally found in a laboratory you are provided with the following materials;

a supply of solid ammonium nitrate,
distilled (deionised) water.

Give a step-by-step description of how you would carry out the experiment to include;

(i) the number of experiments you would do,

(ii) the temperature measurements you would take,

(iii) the volume of water you would use,

(iv) a calculation to show the maximum mass of ammonium nitrate you could use for your volume of water in **(iii)** and a range of masses for the other experiments.

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

[4]

(e) State one hazard that must be considered when planning the experiment and describe a precaution that should be taken to keep risks from this hazard to a minimum. You may use the information in **(c)** if you wish.

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..... [1]

(f) In order to test your prediction in **(a)(ii)**, you would need to plot a graph. In the space below, draw a table with appropriate headings, in which you would record all your experimental data and calculated values necessary for the construction of the graph. The headings **must** include the appropriate units.

[2]

[Total: 15]

For Examiner's Use

2 The solubility of hydrated sodium sulfate, $Na_2SO_4.10H_2O$, in water increases with temperature. At a temperature between 25 °C and 70 °C there is a transition and the solubility becomes that of Na_2SO_4. The units of solubility are grams per one hundred grams of water, g / 100 g water.

An experiment was carried out to investigate this solubility and determine the transition temperature between the two forms of sodium sulfate.

- An empty boiling tube was weighed and the mass recorded.
- Some distilled water was added to the boiling tube and the new mass recorded.
- A small sample of hydrated sodium sulfate was added and this new mass recorded.
- The boiling tube was carefully heated with stirring until all the solid had dissolved.
- The apparatus was cooled slowly while constantly stirring and the temperature recorded when the first crystals appeared in the tube.

(a) The results of several of these experiments are recorded below.

Process the results in the table to calculate the solubility, in g / 100 g water, of the sodium sulfate for each of the temperatures listed.

Record these values to **two decimal places** in the additional columns of the table. You may use some or all of the columns.

Label the columns you use.

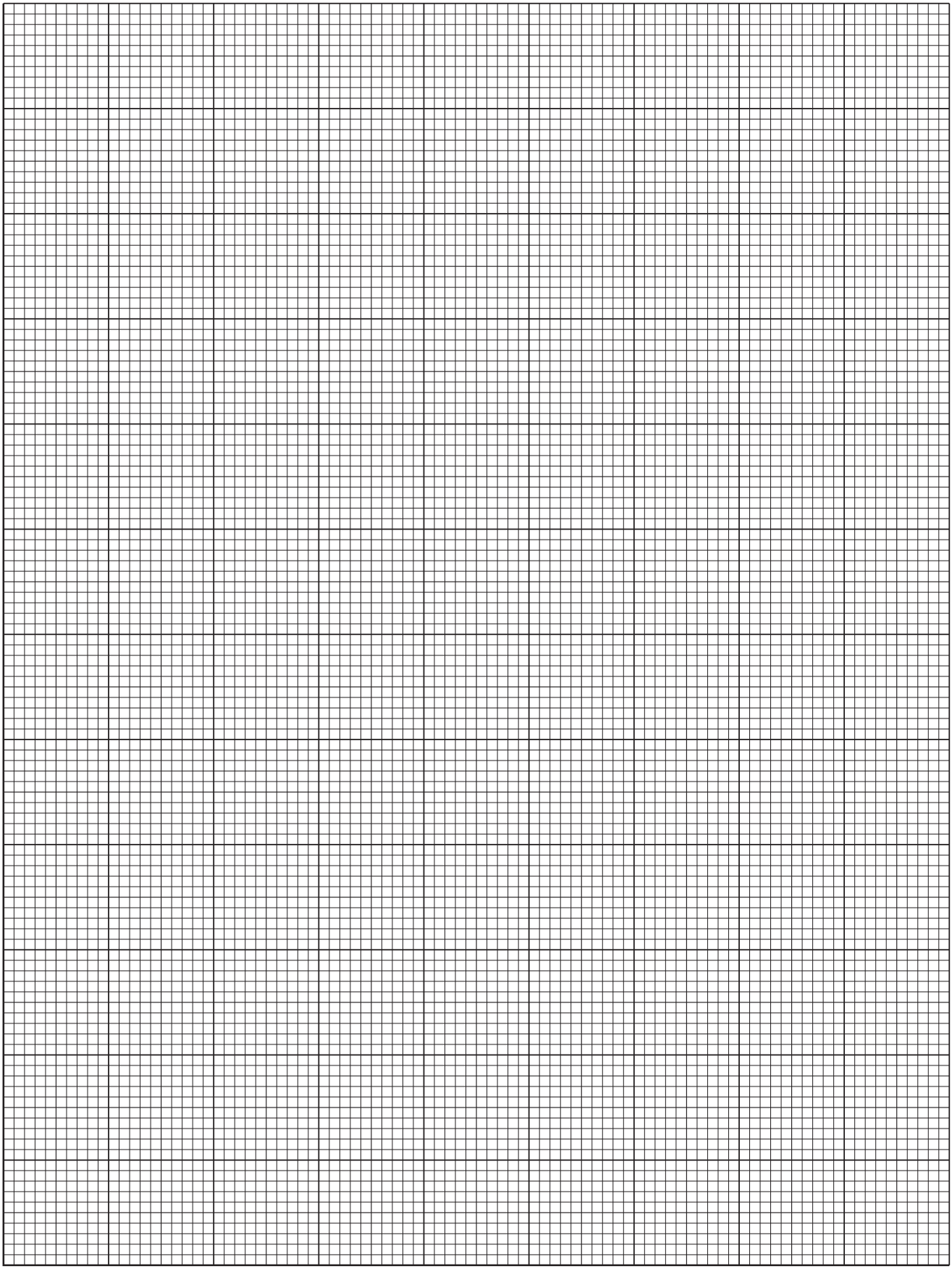
For each column you use include units where appropriate and an expression to show how your values are calculated.

Use the column headings **A** to **H** for these expressions (e.g. **A**–**B**).

A	B	C	D	E	F	G	H
experiment number	mass of boiling tube / g	mass of boiling tube + water / g	mass of boiling tube + water + solid / g	crystallising temperature °C			
1	10.20	35.20	36.45	0.0			
2	10.35	30.35	31.60	10.0			
3	10.10	35.10	40.10	20.0			
4	9.80	29.20	36.96	30.0			
5	9.95	32.95	44.06	40.0			
6	9.90	34.90	46.65	50.0			
7	9.70	30.70	40.32	60.0			
8	10.45	30.45	39.55	70.0			
9	10.05	35.05	46.30	80.0			
10	10.10	40.10	53.45	90.0			

[3]

(b) Plot a graph to show the variation of solubility (*y*-axis) with temperature (*x*-axis).
Draw **two curves** of best fit and extrapolate to locate their intersection at the transition temperature.



[4]

[Turn over

(c) From your graph, state the transition temperature and the solubility at which it occurs.

[2]

(d) (i) In an attempt to repeat the 4th experiment using the same masses of water and solid, the temperature was mistakenly read and recorded before crystals appeared. Place a cross on your graph to represent the point that would have been obtained.

(ii) If this was a valid point, what effect would this have on your transition temperature? Explain your answer.

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.....

[2]

(e) It was found that all the mass recordings in columns **C** and **D** had been made with a balance that had been zeroed incorrectly and they should all have been 0.3 g smaller. The masses recorded in column **B** can be considered to be accurate. Using the corrected masses from experiment 6 calculate the new value of the solubility. By comparing this with the original solubility value for experiment 6 calculate the percentage error difference.

[2]

For Examiner's Use

(f) From the pattern of solubility demonstrated by your graph, predict and explain whether the dissolving of the two forms of sodium sulfate in water are exothermic or endothermic reactions.

prediction for $Na_2SO_4.10H_2O$ .....

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explanation .....

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prediction for Na_2SO_4 .....

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explanation .....

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[2]

[Total: 15]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

7808571428

CHEMISTRY **9701/52**

Paper 5 Planning, Analysis and Evaluation **October/November 2013**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

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UNIVERSITY of CAMBRIDGE International Examinations

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[1]

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> **Ammonium nitrate** NH_4NO_3. Contact with combustible material may cause fire. Explosive when mixed with combustible material.
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Label each piece of apparatus used, indicating its size or capacity and both the temperature range and the precision of the thermometer.

[3]

For Examiner's Use

(d) Using the apparatus shown in **(c)** design an experiment to test your prediction in **(a)(ii)** of how the temperature change of the solution varies with solutions of different concentration.

In addition to the apparatus normally found in a laboratory you are provided with the following materials;

a supply of solid ammonium nitrate,
distilled (deionised) water.

Give a step-by-step description of how you would carry out the experiment to include;

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

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An experiment was carried out to investigate this solubility and determine the transition temperature between the two forms of sodium sulfate.

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(a) The results of several of these experiments are recorded below.

Process the results in the table to calculate the solubility, in g / 100 g water, of the sodium sulfate for each of the temperatures listed.

Record these values to **two decimal places** in the additional columns of the table. You may use some or all of the columns.

Label the columns you use.

For each column you use include units where appropriate and an expression to show how your values are calculated.

Use the column headings **A** to **H** for these expressions (e.g. **A**–**B**).

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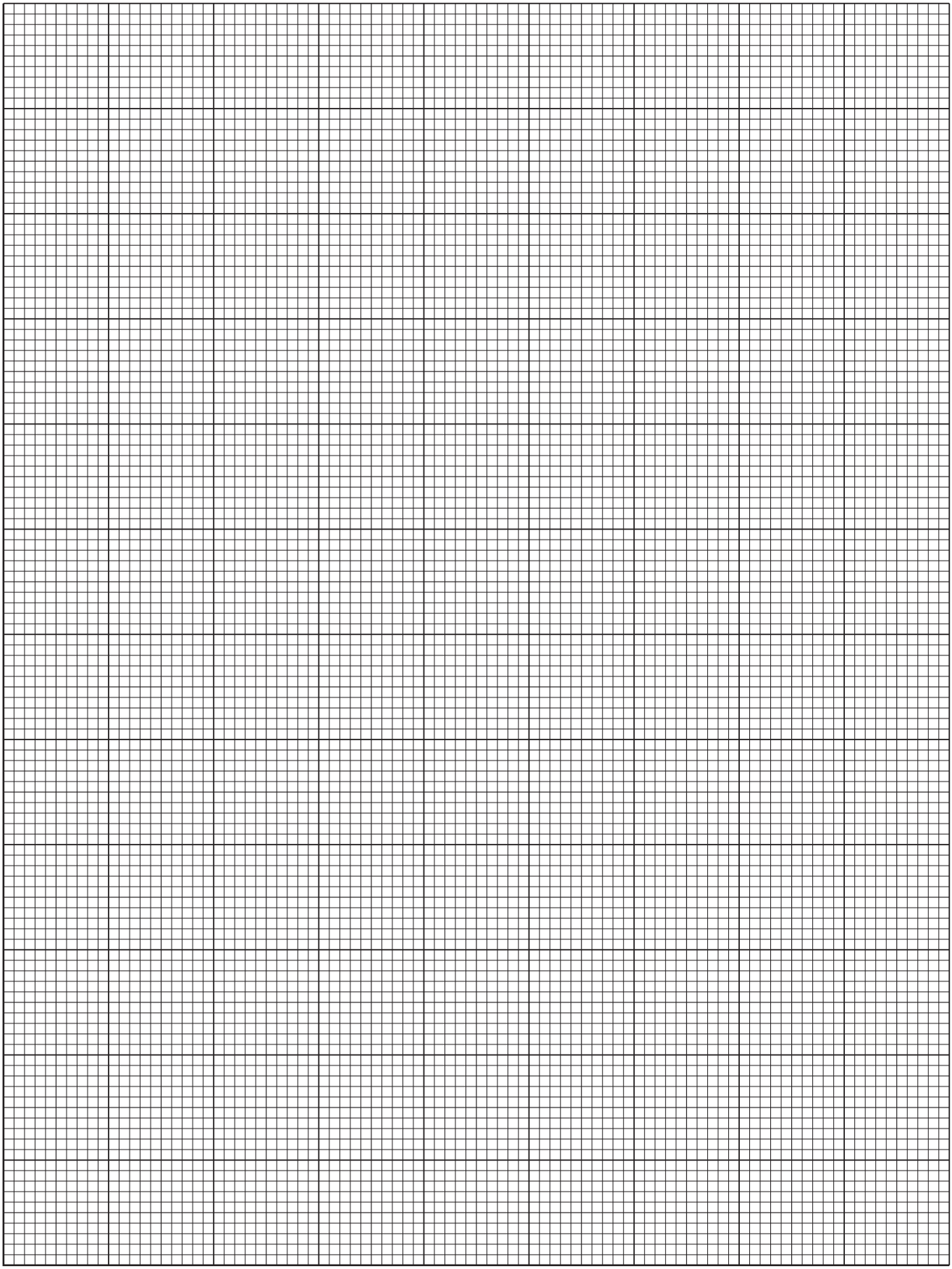

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For Examiner's Use

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prediction for $Na_2SO_4.10H_2O$ .....

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explanation .....

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prediction for Na_2SO_4 .....

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explanation .....

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[2]

[Total: 15]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

9145905666

CHEMISTRY **9701/53**

Paper 5 Planning, Analysis and Evaluation **October/November 2013**

1 hour 15 minutes

Candidates answer on the Question Paper.

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Total	

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UNIVERSITY of CAMBRIDGE International Examinations

For Examiner's Use

1 Air, which is 99% nitrogen and oxygen, is slightly soluble in water. At 25 °C a saturated solution of air in water has a concentration of 19 $cm^3\,dm^{-3}$. When water is boiled all the dissolved air is boiled out of solution.

(a) (i) The molar enthalpies of solution for nitrogen and oxygen are:

$$\Delta H_{soln}\ N_2 = -1.04\ kJ\,mol^{-1} \quad \text{and} \quad \Delta H_{soln}\ O_2 = -1.20\ kJ\,mol^{-1}$$

Predict how the solubility of air in water will change as the temperature is increased. Explain this prediction using Le Chatelier's principle in terms of the equilibrium between air and the aqueous solution as the temperature is increased.

Prediction .....

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Explanation .....

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(ii) Display your prediction in the form of a sketch graph for the solubility of air between 0 °C and 100 °C, labelling clearly the axes. Include labelled points to indicate the solubility of air at 25 °C and 100 °C.

[4]

(b) If you were to carry out an experiment to investigate how the **solubility** of air varies as the **temperature increases** name,

(i) the independent variable, ...

(ii) the dependent variable. .....

[1]

[Total: 5]

2 When heated, aqueous hydrogen peroxide, H_2O_2, decomposes to form oxygen and water.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

The decomposition can also occur at room temperature if a suitable catalyst is added. Both of the solids, manganese(IV) oxide and lead(IV) oxide, will catalyse the decomposition.

The following information gives some of the hazards associated with manganese(IV) oxide and lead(IV) oxide.

> Manganese(IV) oxide: Poisoning can occur by inhalation or swallowing the powder.
>
> Lead(IV) oxide: Poisoning can occur by inhalation or swallowing the powder. The powder can also cause skin irritation.

You are provided with a 0.300 mol dm^{-3} solution of hydrogen peroxide and a syringe with a capacity of 100 cm^3.

(a) Provide the following information about experiments you would carry out to collect oxygen from the decomposition of hydrogen peroxide and to determine, using identical masses, which of the two catalysts was the most efficient at promoting this decomposition:

- a fully labelled diagram of the apparatus to be used that would ensure that no oxygen would be lost when the experiment was carried out,
- a calculation of the maximum volume in cm^3 of the aqueous hydrogen peroxide that could be used such that the oxygen produced would not exceed the volume of the syringe,
- a statement of the measurements you would take that would allow you to say which of the catalysts was most efficient.

The molar volume of a gas at 25 °C is 24.0 dm^3.

Please continue into the space provided on the next page if necessary.

[6]

(b) What other feature of the catalyst should be controlled?

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..... [1]

(c) If one of the experiments takes 2 minutes to complete, draw a sketch graph with labelled axes showing how the volume of oxygen produced will vary with time between 0 and 3 minutes.

[2]

For Examiner's Use

(d) State the hazards that might be encountered when using the solids required in this experiment and give the **one** essential precaution you would take to make sure these chemicals were handled safely during the experiments.

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..... [1]

[Total: 10]

3 In the fractional distillation of two liquids which are miscible (dissolve in each other) in all proportions the more volatile of the two will distil first. At any temperature the composition of the vapour in equilibrium with the liquid has a higher proportion of the more volatile component which has a lower boiling point.

An experiment was carried out to investigate the boiling points of mixtures of tetrachloromethane, CCl_4,and tetrachloroethane, $C_2H_2Cl_4$.

A convenient method for representing the composition of the mixtures, both liquid and vapour, is to use the concept of **mole fraction**. For example, if the liquid mixture consists of 0.15 mole of liquid **A** and 0.35 mole of liquid **B**, the mole fraction of **A** is $\frac{0.15}{(0.15 + 0.35)}$ i.e. 0.30.

(a) The results of several of these experiments are recorded below.

temperature / °C	120.0	108.5	99.3	93.0	89.3	83.3	79.9	76.0
mole fraction CCl_4 liquid	0.000	0.100	0.200	0.300	0.400	0.600	0.800	1.000
mole fraction CCl_4 vapour	0.000	0.469	0.552	0.800	0.861	0.918	0.958	1.000

Calculate the relative molecular masses (M_rs) of CCl_4 and $C_2H_2Cl_4$.

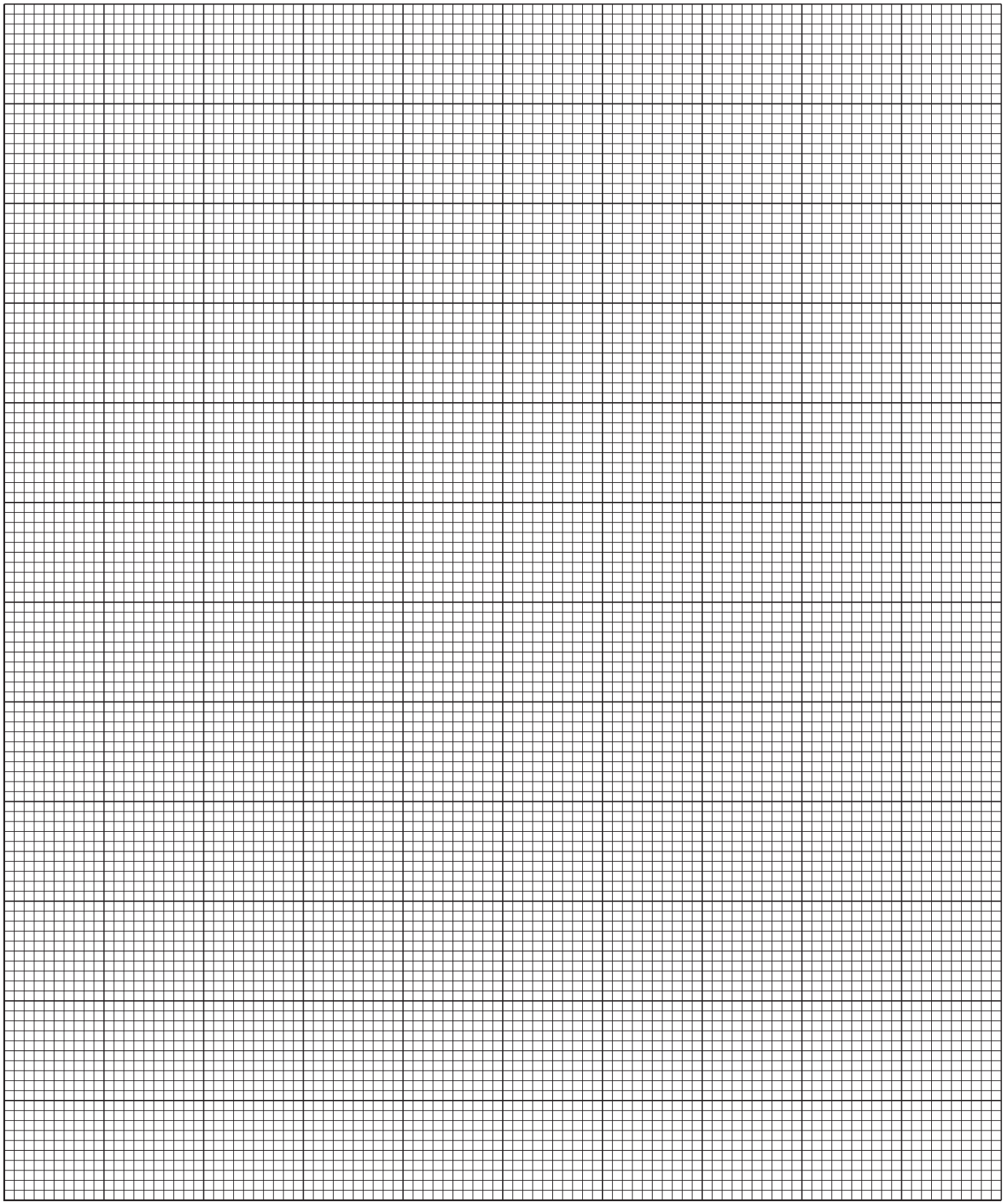
[A_r: H, 1.0; C, 12.0; Cl, 35.5] [1]

(b) (i) The vapour from the equilibrium at 108.5 °C was analysed and found to consist of 7.22 g of CCl_4 and 8.92 g of $C_2H_2Cl_4$. Show clearly by calculation that this gives a mole fraction of 0.469 for CCl_4 vapour.

(ii) The vapour from the equilibrium at 83.3 °C was analysed and found to consist of 14.14 g of CCl_4 and 1.38 g of $C_2H_2Cl_4$. Show clearly by calculation that this gives a mole fraction of 0.918 for CCl_4 vapour.

[2]

(c) On the same axes, plot two graphs, one for the liquid and one for the vapour, to show the variation in temperature (*y*-axis) with the mole fraction compositions (*x*-axis) of both the liquid and the vapour.
Draw **two lines** of best fit. Each line could be either a **curved line or a straight line**.



[4]

[Turn over

For Examiner's Use

(d) Circle and label on the graph the point you consider to be the most anomalous.
Do not circle or label any other point.
If it is assumed that the analysis was carried out accurately, suggest a reason why the point might be anomalous.

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(e) By drawing an appropriate construction line on your graphs, determine the mole fraction of CCl_4 in the vapour which is in equilibrium with a liquid with a mole fraction of 0.500 CCl_4.

[2]

(f) The temperatures were measured using a thermometer calibrated in 0.1 °C graduations. If the thermometer had only been calibrated in 1.0 °C graduations, calculate the percentage errors which would result from the determination of the boiling points of each of the two pure liquids.

[2]

For Examiner's Use

(g) (i) Use your graphs to state whether CCl_4 or $C_2H_2Cl_4$ distills first from a mixture of the two liquids.

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(ii) Explain your answer **(i)**.

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[2]

[Total: 15]

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