UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

5198083856

CHEMISTRY **9701/51**

Paper 5 Planning, Analysis and Evaluation **May/June 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.

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1	
2	
Total	

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

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1 Chlorine gas, Cl_2, is slightly soluble in water, approximately 5 g dm^{-3} at 25 °C. The molar enthalpy of solution of a gas is defined as the enthalpy change when one mole of the gas is dissolved in water.

(a) (i) Predict how the solubility of chlorine in water changes as the temperature is increased. Explain this prediction using Le Chatelier's Principle in terms of the equilibrium between the gaseous chlorine and the aqueous solution, as shown in the equation.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HClO(aq) + HCl(aq) \qquad \Delta H_{soln} = -23.4\,\text{kJ mol}^{-1}$$

Predict how the solubility will change as the temperature is increased. ....

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Explanation ....

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(ii) Display your prediction in the form of a sketch graph between 0 °C and 100 °C. Label the axes with units and give numerical values on the axes to ensure that the line clearly shows the solubility at 25 °C and 100 °C.

[4]

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

(i) the independent variable,

....

(ii) the dependent variable. ....

[1]

(c) You are to plan an experiment to determine as accurately as possible the concentration of a saturated aqueous solution of chlorine by titration. You are reminded that the approximate solubility of chlorine is 5 g dm^{-3} at 25 °C.

The following information gives some of the hazards associated with chlorine, iodine and sodium thiosulfate.

Saturated **chlorine water** is **low hazard** but chlorine gas escapes, which is **harmful**. **Iodine** is **harmful** by inhalation and in contact with skin or eyes. Solutions more concentrated than or equal to 1 mol dm^{-3} are **harmful**. **Sodium thiosulfate** is **non-hazardous**.

Aqueous chlorine, Cl_2, displaces iodine, I_2, from aqueous potassium iodide.

$$Cl_2(aq) + 2KI(aq) \rightarrow I_2(aq) + 2KCl(aq)$$

Therefore if a solution of chlorine is mixed with an excess of aqueous potassium iodide, iodine is displaced in a 1 : 1 molar ratio with chlorine.

The concentration of chlorine in the original solution can therefore be calculated from the concentration of the displaced iodine.

$$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow 2NaI(aq) + Na_2S_4O_6(aq)$$

You are provided with the following materials:

saturated aqueous chlorine,
solid sodium thiosulfate $Na_2S_2O_3.5H_2O$,
concentrated aqueous potassium iodide. This will be used in excess.

Give a step-by-step description of how you would carry out the experiment by including:

(i) a list of apparatus with volumes where appropriate,

(ii) a suitable indicator with relevant colours,

(iii) a calculation of the approximate concentration of saturated aqueous chlorine in mol dm^{-3} at 25 °C,
[A_r: Cl, 35.5]

(iv) a detailed description of the method for preparing a solution of aqueous sodium thiosulfate that can be used in the titration. In a titration, it is usual for the two reacting volumes to be approximately equal at the end-point. Calculate the mass of sodium thiosulfate, $Na_2S_2O_3.5H_2O$, which will produce a solution suitable for use in this titration. The relevant calculations and reasoning must be shown in full,
[A_r: H, 1.0; O, 16.0; Na, 23.0; S, 32.1]

(v) a detailed method for carrying out sufficient titrations to allow an accurate end-point to be obtained,

(vi) an outline calculation to show how the results are to be used to determine the accurate concentration of the aqueous chlorine.

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.... [8]

(d) 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 should use the information in **(c)**.

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.... [2]

[Total: 15]

QUESTION 2 STARTS ON THE NEXT PAGE.

2 Hydrated iron(II) sulfate can be represented as $FeSO_4.xH_2O$ where x is the number of molecules of H_2O for each $FeSO_4$. When the compound is heated, it loses the molecules of water leaving anhydrous iron(II) sulfate.

A suggested equation is:

$$FeSO_4.xH_2O(s) \rightarrow FeSO_4(s) + xH_2O(g)$$

An experiment is carried out to attempt to determine the value of x.

- An open crucible is weighed and the mass recorded.
- A sample of hydrated iron(II) sulfate is added to the crucible and the new mass recorded.
- The crucible with hydrated iron(II) sulfate is heated strongly for five minutes and allowed to cool back to room temperature.
- The crucible with the contents is reweighed and the mass recorded.

(a) Calculate the relative formula masses, M_r, of $FeSO_4$ and H_2O.
[A_r: H, 1.0; O, 16.0; S, 32.1; Fe, 55.8]

[1]

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

Process the results in the table to calculate both the number of moles of anhydrous iron(II) sulfate and the number of moles of water.

Record these values in the additional columns of the table.
You may use some or all of the columns.

Masses should be recorded to **two decimal places**, while the numbers of moles should be recorded to **three significant figures**.

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

You may use the column headings A to G for these expressions (e.g. A–B).

A	B	C	D	E	F	G
mass of crucible / g	mass of crucible + $FeSO_4.xH_2O$ / g	mass of crucible + $FeSO_4$ / g				
15.20	17.03	16.20				
15.10	17.41	16.41				
14.95	17.33	16.25				
15.15	17.70	16.54				
15.05	17.79	16.55				
14.90	17.88	16.53				
14.92	18.18	16.70				
15.30	18.67	17.14				
15.07	18.64	17.02				
15.01	18.80	17.04				

[2]

(c) Plot a graph to show the relationship between the number of moles of anhydrous iron(II) sulfate, $FeSO_4$ (*x*-axis), and the number of moles of water (*y*-axis).
Draw the line of best fit. It is recommended that you do not include the origin in your choice of scaling.

[3]

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(d) Circle and label on the graph any point(s) you consider to be anomalous.
For each anomalous point give a different reason why it is anomalous clearly indicating which point you are describing.

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.... [3]

(e) Determine the slope of the graph. You must mark clearly on the graph any construction lines and show clearly in your calculation how the intercepts were used in the calculation of the slope.

[3]

(f) Comment on the reliability of the data provided in **(b)**.

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.... [1]

(g) **(i)** Use the value of the slope of your graph calculated in **(e)** to suggest the correct formula for hydrated iron(II) sulfate.

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

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[2]

[Total: 15]

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