Class:



DUNMAN HIGH SCHOOL Preliminary Examination Year 6

H2 CHEMISTRY

Paper 2 Structured

9647/02

2 hours

14 September 2012

Additional Materials: Data Booklet

INSTRUCTIONS TO CANDIDATES

- 1 Write your **name**, **index number** and **class** on this cover page.
- 2 Answer *all* questions.
- 3 Write your answers in the spaces provided on the question paper.
- 4 A Data Booklet is provided.
- 5 The number of marks is given in brackets [] at the end of each question or part question.
- 6 You may use a calculator.

FOR EXAMINER'S USE								
Question No.	1	2	3	4	5	6	Total	%
Marks	12	14	8	18	10	10	[72]	

Answer all questions in the space provided.

1 Planning

This question is about the kinetics of urease–catalysed hydrolysis of urea in phosphate and citrate buffer solutions.

Urease is an enzyme that breaks down urea, $CO(NH_2)_2$, into carbon dioxide and ammonia. The production of ammonia raises the pH of the buffered solution mixture and can be detected using a suitable acid–base indicator.

$$CO(NH_2)_2 + H_2O \otimes CO_2 + NH_3$$

Urease is active over a wide range of pH so a few indicators can be used provided that the original solution mixture is buffered at the right pH to start with.

The colour change of bromomothymol blue and phenolphthalein in acid-base medium is shown in the table:

Indicator	pK ind	pH range	Colour change
bromothymol blue	7.0	5.9–7.6	Yellow(in acid) – blue (in alkali)
phenolphthalein	9.3	8.3–10.0	Colourless(in acid)-pink (in alkali)

Phosphate and citrate present in the buffer solutions do not react with urea or urease.

In order to study the effect of the enzyme concentration on the rate of hydrolysis of urea, you are provided with

- · Choice of two indicators, bromothymol blue and phenolphthalein
- Choice of two buffered solutions, phosphate buffer at pH 7 and citrate buffer at pH 5
- 2% of urea solution
- 3% urease solution
- distilled water

In a preliminary experiment, a solution mixture containing 20 cm³ of urea solution, 8 cm³ of buffer solution, 6 cm³ of urease solution, 6 cm³ of water took 40 seconds for the indicator to show a colour change.

It is found that the time taken for the indicator in the reaction mixture to change colour doubled when urease used is diluted with an equal amount of water.

(a) (i) Suggest the appropriate choice of indicator and the buffer solution used in the preliminary experiment.

Choice of buffer solution:

Choice of indicator:

(ii) Using the results of the preliminary experiment predict the relationship between the rate of hydrolysis of urea and concentration of urease.

[2]

(b) (i) A student designed a series of experiments to investigate the prediction in the preliminary experiment by **initial rate method**.

Complete the table below to show

- all volumes to be used such that a simple comparison of the time taken for end–point of the indicator can be made with the preliminary experiment.
- how the measurements would be processed(that is, complete the heading for the last column) to enable the student to confirm or reject the preliminary prediction.

Expt	Volume of urea/ cm ³	Volume of urease/ cm ³	Volume of buffer/ cm ³	Volume of water/ cm ³	Time taken, t/ s	
Р	20	6	8	6	40	
1						
2						
3						

P: Preliminary experiment

- (ii) Outline the procedural steps that the student would take to carry out the designed experiments in (b)(i),stating any assumption(s) made.
 Your plan should include:
 - o the apparatus used to measure the various volumes;

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- o the sequence that the various solutions are mixed;
- o how the time for the colour change of indicator is measured; and
- o other experimental details to ensure the consistency of the experiment.

You may also assume that standard laboratory apparatus are available.

(iii) Explain how the results of the experiments will confirm or reject the preliminary prediction.

(c) The rate of this reaction is also studied when the temperature is varied. Give a sketch of a graph to show how the rate will vary with temperature. Explain the shape of your sketch.



[2]

[Total: 12]

- 2 Ethanoic acid, also commonly known as acetic acid, is an important chemical due to its varied uses in the industry.
 - (a) The preferred industrial method for its manufacture is by carbonylation of methanol, an exothermic reaction, accounting for 65% of the total world ethanoic acid manufacturing capacity.

 $CH_3OH(aq) + CO(g) \longrightarrow CH_3CO_2H(aq)$

The conditions employed are:

- 150 200 °C
- 30 60 atm
- rhodium–based catalyst

Using Le Chatelier's Principle, explain why the above moderate pressure is chosen as the process condition.

[2]

(b) The graph below shows the changes in pH when a 25.0 cm³ sample of vinegar, with ethanoic acid as its main component, is titrated against 0.45 mol dm⁻³ aqueous sodium hydroxide.



(i) Using the information provided, show by calculations that the acid dissociation constant, K_a of ethanoic acid has an approximate numerical value of 1.85 x 10⁻⁵.

(ii) State a suitable indicator for this titration. Explain your choice.

Indicator:		
Reason for choice:		
		[5]

- (c) The buffer produced at region A in (b) consists of a weak acid and its conjugate base.
 - (i) Draw a diagram to illustrate the shape of the anion present. State the shape about each carbon atom and its respective bond angles.

- (ii) With clear reference to your drawing in **c(i)**, state the type of hybridisation present for each carbon atom in the anion.
- (iii) The boiling points of both components of the buffer are given below.

weak acid	118 °C
conjugate base	881 °C

With reference to the structures and interactions present, account for the large difference in the boiling points shown.

[7]

[Total: 14]

3 (a) Sodium chlorate(I), NaC/O, found in household bleach produces chlorine upon addition of acidified dilute hydrochloric acid according to the equation below.

 $ClO^{-}(aq) + 2H^{+}(aq) + Cl^{-}(aq) \otimes Cl_{2}(aq) + H_{2}O(l)$

A 10.0 cm³ sample of a household bleach is diluted to 100 cm³. 25.0 cm³ of this solution is then pipetted out into a conical flask containing dilute hydrochloric acid. Excess potassium iodide solution is added and the resultant solution turns brown. This resultant solution is then titrated against 0.100 mol dm⁻³ sodium thiosulfate solution and required 15.20 cm³ for complete reaction.

- (i) Identify the specie that is responsible for the brown colouration and state the reaction that has taken place.
- (ii) Calculate the concentration of the sodium chlorate(I) in the household bleach in g dm⁻³.

concentration=g dm⁻³
[4]

(b) A small portion of three unlabelled samples of KC*l*, KBr and KI are reacted with concentrated phosphoric acid separately and each of the hydrogen halide gases produced are immediately passed through identical set–ups as shown.

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(i) Suggest a hydrogen halide that can be identified using this set–up, clearly stating the equation of the reaction taking place and the expected observations for the organic layer.

Hydrogen halide:	
Equation:	
Expected observati	ons:

(ii) Describe a chemical test that can be carried out to distinguish between the two remaining potassium halide solutions and explain the expected observations.

[Total: 8]

[Turn over

4 (a) Magnesium oxide is one of the products formed when magnesium carbonate decomposes.

MgCO₃(s) **®** MgO(s) + CO₂(g) $DH^{\bullet} = +100 \text{ kJ mol}^{-1}$

(i) The decomposition of magnesium carbonate was studied at two different temperatures, to determine the ideal temperature for the industrial production of magnesium oxide. The products were bubbled into limewater and the observations are as follows:

Temperature / K	Effect on limewater
1050	White precipitate
400	No white precipitate

At a certain temperature, it was found that the reaction ceases to be feasible. Given the following entropy values, determine this temperature.

Compound	Entropy / J mol ⁻¹ K ⁻¹
MgCO ₃ (s)	65.7
MgO(s)	26.9
CO ₂ (g)	213.6

T=.....

(ii) Hence, suggest why it is necessary to determine the unknown temperature instead of carrying out the industrial production of magnesium oxide at 1050K.

(iii) Using the data provided and relevant data from the *Data Booklet*, construct an appropriate fully-labelled energy cycle to calculate the lattice energy of magnesium carbonate.

Enthalpy Term	DH / kJ mol⁻¹
Enthalpy change of atomisation of magnesium	+148
Sum of 1 st and 2 nd electron affinities of oxygen	+657
Enthalpy change of formation of magnesium carbonate	-1096
Enthalpy change of formation of CO ₂ (g)	-393
$O^{2-}(g) + CO_{2}(g) \otimes CO_{3}^{2-}(g)$	-778

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- (b) The plots of pV/RT against p for one mole of an ideal gas and one mole of carbon dioxide gas from the decomposition of magnesium carbonate at 300K are given below.
 - (i) Show, on the same axes, how one mole of sulfur dioxide, SO₂ will behave at the same temperature of 300K. Label your graph clearly.



(ii) Explain the difference in behavior between carbon dioxide and sulfur dioxide at 300K.

(iii) Explain what happens when sulfur dioxide gas is cooled to 100K. Illustrate your answer clearly on the same axes in **b(i)**.

[4]

(c) The temperatures for the thermal decomposition of carbonates of Group II elements magnesium to radium are as shown.

Compound	Decomposition Temperature / °C
MgCO₃	540
CaCO ₃	900
SrCO ₃	1290
BaCO ₃	1350
RaCO ₃	720

It was suggested that the decomposition temperature for radium carbonate to be 720 °C. Comment on the accuracy of this suggestion.

(d) Write appropriate equations to illustrate the reactions of PCl_3 and $AlCl_3$ with water. Hence, state the observations when they are separately added to test tubes containing aqueous magnesium carbonate.

PC <i>l</i> ₃	
AICI3	

[4]

[3]

[Total: 18]

5 The diagram below shows the synthetic pathway by which compound **F** may be prepared. The inorganic side product, which is produced together with compound **F**, is constantly removed from the reaction mixture.

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(a) Give the structural formulae for compounds D and E.



(b) Suggest the reagents and conditions for steps 2 and 3.

Step 2:	
Step 3	
	[2]

- (c) Draw the structures of the organic products formed when compound **F** is reacted with each of the following:
 - (i) Cl_2 in $AlCl_3$, room temperature

(ii) KOH(aq), reflux

(iii) cold dilute nitric acid

(d) Describe a chemical test that can be used to distinguish between compounds A and B. Reagent(s) & conditions:

Observations:

[2]

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[Total: 10]

6 The reaction scheme below shows the final stages in the synthesis of compound **S**.



(a) Draw the displayed formulae of compounds R and Q.

(b) Give the synthetic route, involving *not more than three steps*, from **P** to **Q**. In your answer, suggest the reagent(s) and conditions involved in each step and draw the structural formulae of the intermediate organic products. Name the type of reaction occurring at each step.

- [6]
- (c) In the reaction of **R** and **Q**, another organic compound can also possibly be formed. Draw the structural formula of the organic compound and explain how its formation may arise.

[Total: 10]