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Promotional Examination II 2009
Pre-university 2

H1 CHEMISTRY 8872
PAPER 2   **8872 / 2**

Wednesday   23 September 2009   2 h

Additional materials:
Answer booklet
Cover page
Data Booklet
5 pieces of writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name, index number and class on all the work you hand in.
Write in dark blue or black pen on both sides of the writing paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluids.

Section A
Answer **all** questions.

Section B
Answer any **two** questions on the writing papers. Start each new question on a fresh sheet of writing paper.

At the end of the examination, hand in your answers to Section A and Section B separately.
Attach the cover page to your answer scripts for Section B.

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE								
Section	**A**				**B (2 questions)**			**Total**
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	
Marks	10	10	10	10	20	20	20	80

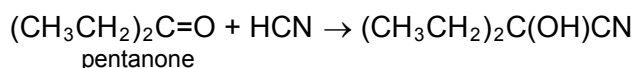**This question paper consists of 15 printed pages.**

[Turn over

Section A
Answer ALL questions in the spaces provided.

1. (a)   What do you understand by the term *order of reaction*?   [1]

   ....

   ....

   (b) Cyanohydrins can be converted easily to useful organic acids. To form cyanohydrins, ketones are reacted with a basic solution of sodium cyanide.

$$(CH_3CH_2)_2C=O + HCN \rightarrow (CH_3CH_2)_2C(OH)CN$$
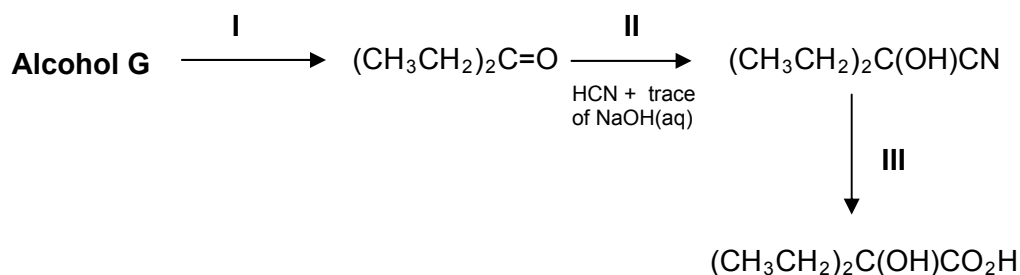   pentanone

   The above reaction was carried out with different concentrations of the three reagents and the following results were obtained and recorded in the table below.

Experiment number	$[(CH_3CH_2)_2C=O]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	$[CN^-]$ / mol dm^{-3}	Relative initial rate
1	0.0400	0.0600	0.0600	2.000
2	0.0400	0.0400	0.0500	1.666
3	0.0500	0.0800	0.0500	2.084

   A chemist determined that the order of reaction is zero with respect to hydrogen ions. Deduce the order of reaction with respect to pentanone and cyanide ions. Hence write a rate equation for the reaction.   [3]

(c) $(CH_3CH_2)_2C(OH)CN$ can be synthesized from **Alcohol G** by the following series of reactions.

Alcohol G $\xrightarrow{\text{I}}$ $(CH_3CH_2)_2C=O$ $\xrightarrow[\substack{\text{HCN + trace} \\ \text{of NaOH(aq)}}]{\text{II}}$ $(CH_3CH_2)_2C(OH)CN$

$\downarrow$ **III**

$(CH_3CH_2)_2C(OH)CO_2H$

(i) State the name of **Alcohol G.** [1]

....

(ii) Suggest reagents and conditions for reactions **I** and **III**. [2]

Reaction **I**: ....

Reaction **III**: ....

(iii) $(CH_3CH_2)_2C(OH)CO_2H$ produced in the above reaction is soluble in water. With the aid of suitable diagrams, explain how this is so. [2]

....

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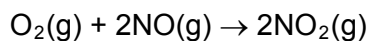...

(iv) State the structural formula of the organic compound formed when **Alcohol G** is refluxed with propanoic acid in the presence of concentrated sulphuric acid. [1]

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[Turn over

2. (a) A key reaction in production of acid rain is the formation of nitrogen dioxide gas. This gas is produced from the reaction between nitrogen monoxide and oxygen.

$$O_2(g) + 2NO(g) \rightarrow 2NO_2(g)$$

(i) Given the following data, calculate the enthalpy change for the above reaction. Show your workings clearly. [1]

Substance	ΔH_f / kJ mol^{-1}
NO(g)	+ 90.3
NO$_2$(g)	+ 33.2

(ii) Sketch a <u>clearly labelled</u> energy profile diagram in the space below for the above reaction, assuming it is a one-step reaction. Include the enthalpy change value calculated in (i) on the diagram. [2]

(b) Oxides of sulphur are also responsible for the formation of acid rain. In the laboratory, at room temperature, the presence of sulphur dioxide gas can be confirmed with an acidified solution of potassium dichromate(VI). The equation for this reaction is shown below.

$$3\underline{S}O_2\,(g) + Cr_2O_7^{2-}\,(aq) + 2H^+\,(aq) \rightarrow 3\underline{S}O_4^{2-}\,(aq) + 2Cr^{3+}\,(aq) + H_2O\,(l)$$
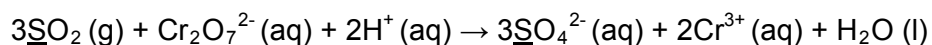
(i) State the oxidation number of sulphur in SO_2 and SO_4^{2-} in the equation above. [1]

O.N. of S in SO_2 : .... 　　　　　　O.N. of S in SO_4^{2-} : ....

(ii) A sample of sulphur dioxide reacts exactly with 50.0 cm^3 dichromate(VI) solution. The resulting chromium(III) solution is found to be 0.120 mol dm^{-3}. Calculate the volume of sulphur dioxide used in the reaction. [2]

(iii) Describe, with the aid of a balanced equation, the reaction of sulphur dioxide with water. Suggest an approximate pH for the resulting solution. [2]

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(iv) The boiling points of SO_2 and SO_3 are -10°C and 45°C respectively. With reference to their intermolecular forces of attraction, explain this difference. [2]

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[Turn over

3. (a) In the synthesis of various types of organic compounds, 2-chlorobutane is a useful reagent. One of the reactions that 2-chlorobutane can undergo is elimination reaction to form but-2-ene (M_r = 56.0) which exhibits *cis-trans isomerism*.

(i) Draw the structural formula of the *cis* and *trans* isomers of but-2-ene in the space provided below.   [2]

cis but-2-ene	*trans* but-2-ene

(ii) But-2-ene undergoes oxidation with hot acidified concentrated potassium manganate (VII) to form an organic product. Draw the **displayed formula** of this product.   [1]

(iii) A student used the apparatus below to determine the enthalpy change of combustion of but-2-ene. It was found that 0.56 g of but-2-ene was used to raise the temperature of 200 g of water. The initial temperature of the water was 17.4°.
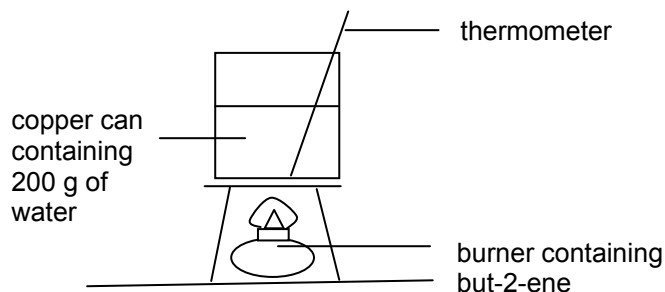
With reference to the Data Booklet and given that the enthalpy change of combustion is -2025 kJ mol^{-1}, calculate the final temperature of the water.   [3]

(iv) The theoretical initial temperature of water was found to be lower than the value given in (iii). Provide a possible explanation for this.   [1]

....

....

(b) 2-chlorobutane can be converted to a 2° alcohol.

(i) State what type of reaction this is.   [1]

....

[Turn over

(ii)   The above reaction requires approximately 25 minutes for completion. Predict the amount of time required for the reaction to complete when 2-bromobutane is used instead. Explain your answer.   [2]
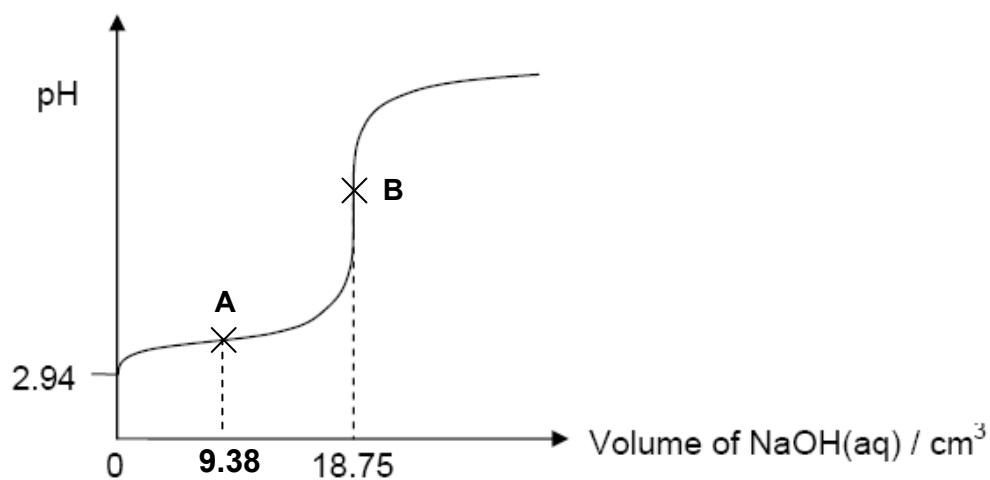
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4. (a) Propanoic acid is a *weak acid*. Explain the term in italics.   [1]

....

....

(b) 25.0 cm³ sample of propanoic acid was titrated with 0.10 mol dm⁻³ sodium hydroxide. By using a pH meter, the following graph was obtained.

(i)   Describe briefly what happens at Point **A** and **B** respectively.   [2]

....

....

....

....

....

(ii)   With reference to the graph above, prove through calculations that the K_a for propanoic acid is approximately 1.8 x 10^{-5} mol dm^{-3}.   [3]

(iii)   A solution containing propanoic acid and its sodium salt sodium propanoate, $CH_3CH_2CO_2Na$, acts as a buffer solution which resists pH change. Construct suitable equations showing how this is possible.   [2]

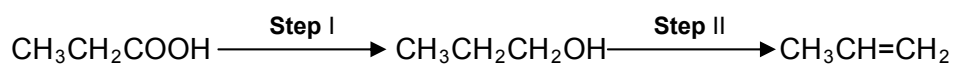...

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(c)   Propanoic acid can be converted to propene in a series of reactions as shown below:

$CH_3CH_2COOH \xrightarrow{\textbf{Step I}} CH_3CH_2CH_2OH \xrightarrow{\textbf{Step II}} CH_3CH=CH_2$

State reagents and conditions for Steps **I** and **II**.   [2]

....

....

....

....

[Turn over

SECTION B (40 marks)

Answer only 2 out of the 3 questions.

1. Similar to graphite, boric acid, $B(OH)_3$, has a structure that allows it to act as a solid lubricant. Boric acid has a melting point of 171 ^oC and a boiling point of 300 ^oC.

   While boric acid is commonly used as an insecticide, a dilute water solution of boric acid is also used as a mild antiseptic and eyewash. Boric acid dissolves in water according to the equation:

   $$B(OH)_3 \text{ (aq)} + H_2O \text{ (l)} \rightleftharpoons B(OH)_4^- \text{ (aq)} + H^+ \text{ (aq)}$$
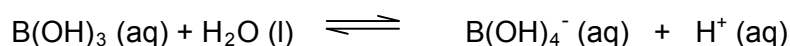
   The acid dissociation constant, K_a, of boric acid is 5.8×10^{-10} mol dm^{-3}.

   (a) (i) Draw a diagram of a molecule of $B(OH)_3$ and identify **all** the bond angles in the molecule.
      (ii) Using the data above, deduce the structure and types of chemical bonds present in boric acid. [6]

   (b) Aqueous boric acid was titrated with potassium hydroxide, using a suitable indicator.
      (i) Name a suitable indicator for this titration and explain your choice.
      (ii) Draw a dot-and-cross structure of $B(OH)_4^-$.
      (iii) Like boric acid, one Period 3 chloride reacts with water to form a weakly acidic solution. Identify this chloride and write chemical equations to illustrate its reaction with water.
      (iv) When sufficient aqueous potassium hydroxide was added to boric acid for complete reaction, suggest a value of the pH of the resulting solution.

      [6]

   (c) 1 mol of boric acid was added to 1 dm^3 of H_2O. A graph of the rate of the forward reaction was obtained as shown below.
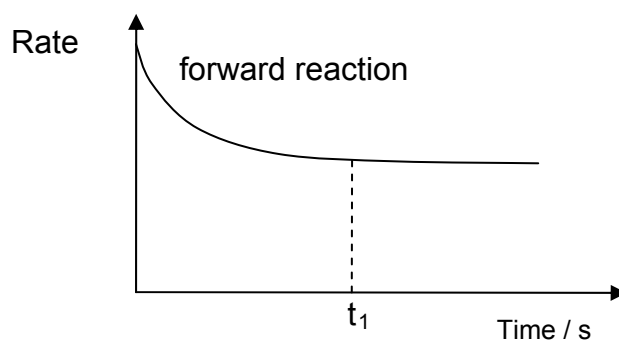
   (i) Describe what is happening at time t_1.

(ii) By copying the graph above on your paper, sketch the graph that represents the rate of the backward reaction on the same graph.

(iii) Explain what happens to the pH of the solution when another 1 mole of boric acid solid is added to this solution.

[4]

(d) Boronic acid has an alkyl or aryl group substituted on boric acid. It has a general formula $B(OH)_2R$, where R is an alkyl or aryl group.

The K_a value of boronic acids can be estimated based on understanding of the effect of substituent groups on acidity of a substance. The table below shows the K_a values of some other organic substances at 298 K.

Substance	Ethanoic acid	$B(C_6H_5)(OH)_2$	Ethanol	$BCH_3(OH)_2$
K_a / mol dm^{-3}	1.8×10^{-5}	1.3×10^{-9}	x	y

K_w is the ionic product of water and has a value 1.0×10^{-14} mol^2 dm^{-6}.

(i) Explain the acidity of ethanoic acid based on its structure.

(ii) Based on the K_a value of boric acid and suitable information above, suggest possible range of values of x and y.

[4]

Total: 20 marks

[Turn over

2. Carbohydrates compose of elements carbon, hydrogen and oxygen. The ratio of hydrogen and oxygen atoms in a carbohydrate molecule is 2:1. Lactose, $C_{12}H_{22}O_{11}$, is a common carbohydrate found in milk. The sour taste of spoilt milk is due to bacterial fermentation of lactose.

lactose → Bacterial fermentation → lactic acid
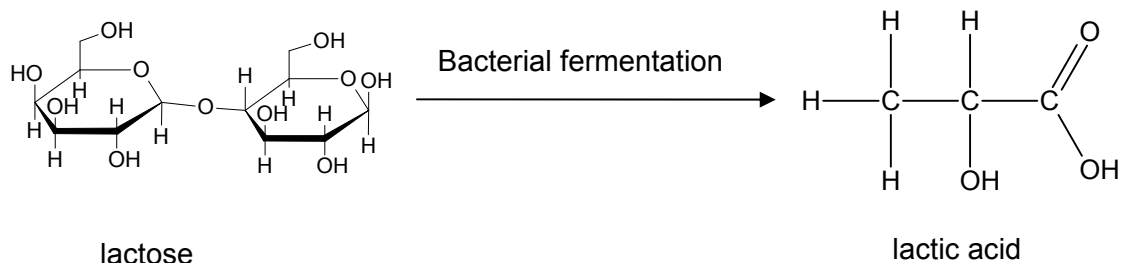
(a) The molecular formula of a carbohydrate can be found by elemental analysis.

    (i) Define molecular formula.

    (ii) A substance contains 41.0% carbon, 4.5 % hydrogen and 54.5% oxygen. Determine if the substance is a carbohydrate.

    (iii) Briefly state how you can find the molecular formula of the substance in (aii).

                                                                                         [5]

(b) Lactate is a product of metabolism of glucose through muscular activity. Enzyme **P** catalyses the redox reaction between pyruvate and NADH. An equilibrium is established between the reactants and products.

The half equations are:

$$NADH \rightleftharpoons NAD^+ + H^+ + 2e^-$$

pyruvate $+ 2H^+ + 2e^- \rightleftharpoons$ lactate
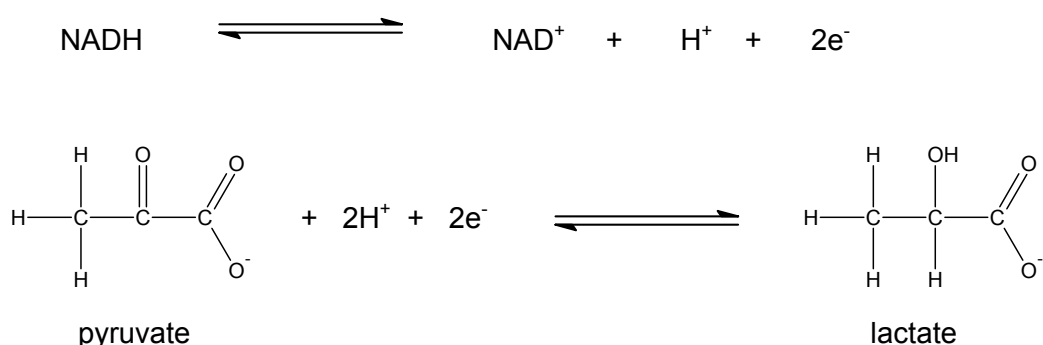
    (i) Write a balanced redox equation using the half equations provided.

    (ii) Describe what an enzyme is.

    (iii) Explain how activation energy is affected by enzyme **P**. Hence, explain and illustrate using the Maxwell-Boltzmann distribution curve, how the presence of enzyme **P** increases rate of reaction.

(iv) Deduce the effect on the value of the equilibrium constant when enzyme **P** is removed.

[5]

(c) Lactic acid can be formed by 2 other chemical methods in a laboratory. Suggest 2-step reactions to convert the following compounds to lactic acid. State reagents and conditions in each step clearly. Draw the structure of intermediate compounds formed.

(i) ethanal

(ii) 2-chloropropan-1-ol

[6]

(d) Another possible starting material for synthesis of lactic acid is prop-2-enoic acid.
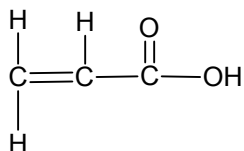
Suggest 2 chemical tests to confirm the identities of prop-2-enoic acid and lactic acid present in separate unlabelled test-tubes. State any observations clearly.   [4]

Total: 20 marks

3. Nitrogen trichloride, NCl_3, is a foul smelling substance which can be formed by the following reaction:

$$4 \, NH_3 \, (g) + 3 \, Cl_2 \, (g) \rightarrow NCl_3 \, (l) + 3 \, NH_4Cl \, (s)$$
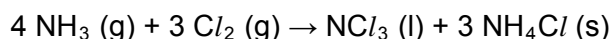
During the reaction, chloramines NH_2Cl and $NHCl_2$ can be formed as intermediates. NH_2Cl has applications as a disinfectant in water supplies. However, it can react with organic compounds in water to form chlorocarbons which are harmful to humans.

(a) Ammonia can be produced by the Haber process using iron as a catalyst:

$$N_2 \, (g) + 3H_2 \, (g) \xrightleftharpoons{\Delta H_1} 2NH_3 \, (g)$$
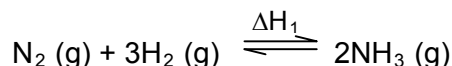
   (i) Apart from the use of a catalyst, describe and explain **one** of the other conditions used in the Haber process.

   (ii) Using relevant bond energy values from the Data Booklet, find the enthalpy change of the forward reaction, ΔH_1.

   (iii) Use this value to find the unknown enthalpy change of reaction, ΔH_3, in the energy level diagram below.

Energy / kJ mol^{-1}

N$_2$ (g) + 3H$_2$ (g)

ΔH_3 = ?

2NH$_3$ (g)

ΔH_2 = + 46 kJ mol^{-1}

2NH$_3$ (l)
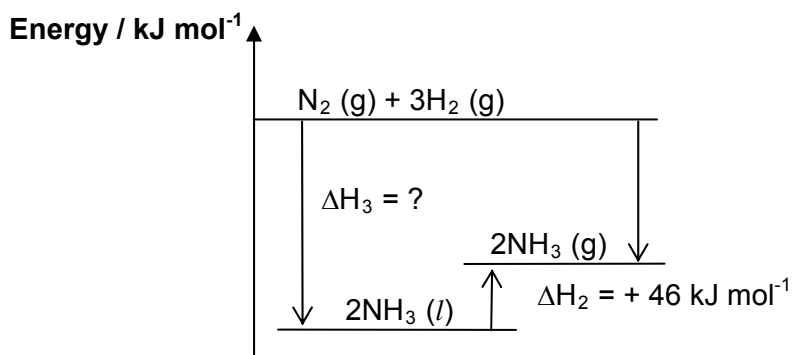
[5]

(b) 50 cm^3 of NH_3 gas and 10 cm^3 of Cl_2 gas were mixed in a closed vessel at room temperature and pressure.

   (i) Find the maximum amount (in mol) of NCl_3 that can be produced.

   (ii) The rate of reaction between NH_3 and Cl_2 can be investigated by recording changes in total pressure of the closed system. Suggest how you can confirm if the reaction is first order with respect to Cl_2.

[4]

(c) Chloramines are reactive only towards certain organic compounds.

(i) Predict and explain if NH_2Cl can react with ethane.

(ii) Provide 2 reasons why the following reaction will not occur:

[4]
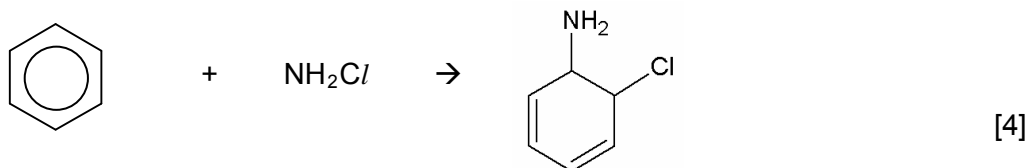
(d) An unknown compound **X** belongs to a group of compounds with general formula **RNCl$_2$**. In compound **X**, **R** has a molecular formula C_8H_7O. It is found that the **R** group reacts with Tollen's reagent but not with Fehling's reagent. Compound **X** reacts with hot concentrated acidified $KMnO_4$ to form a substance **Y** that reacts with 2 moles of $NaHCO_3$.

(i) Deduce and draw the structural formulae of **X** and **Y**.

(ii) Write a balanced equation of the reaction of substance **Y** with $NaHCO_3$.

[4]

(e) An unknown element **Q** in period 4 forms a chloride with a boiling point of 201°C. It dissolves in water readily to form an acidic solution. In solid state, the chloride of **Q** exists as a dimer with molecular formula **Q$_2$Cl$_6$**.

(i) Deduce the identity of element **Q**.

(ii) Write the electronic configuration of **Q.**

(iii) Explain why the reaction between element **Q** and chlorine gas is a redox reaction.

[3]

Total: 20 marks

- END OF PAPER-