



22086114



CHEMISTRY
HIGHER LEVEL
PAPER 2

Thursday 8 May 2008 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

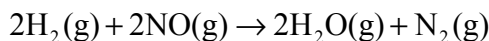
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.



SECTION A

Answer **all** the questions in the spaces provided.

- 1. Hydrogen and nitrogen(II) oxide react together exothermically as follows.



The rate of this reaction was investigated in a series of experiments carried out at the same temperature, the results of which are shown in the table below.

Experiment	Initial $[\text{H}_2(\text{g})]$ / mol dm^{-3}	Initial $[\text{NO}(\text{g})]$ / mol dm^{-3}	Initial rate of reaction / $\text{mol dm}^{-3} \text{ s}^{-1}$
1	2.0×10^{-3}	4.0×10^{-3}	4.0×10^{-3}
2	4.0×10^{-3}	4.0×10^{-3}	8.0×10^{-3}
3	6.0×10^{-3}	4.0×10^{-3}	
4	2.0×10^{-3}	2.0×10^{-3}	1.0×10^{-3}
5	2.0×10^{-3}	1.0×10^{-3}	

- (a) Explain how the results from Experiments 1 and 2 can be used to deduce that the order of reaction with respect to hydrogen is 1. [1]

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- (b) Deduce the order of reaction with respect to nitrogen(II) oxide, giving a reason for your answer. [2]

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- (c) Use your answers from parts (a) and (b) to deduce the rate expression for the reaction. [1]

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- (d) Complete the table above by calculating the rate of reaction for each of Experiments 3 and 5 (write your answers in the table). [2]

(This question continues on the following page)



(Question 1 continued)

- (e) Use the results from Experiment 1 to determine the value of, and the units for, the rate constant, k , for the reaction. [2]

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- (f) Suggest a mechanism for the reaction that is consistent with the rate expression. [2]

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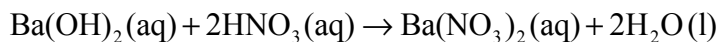
- (g) The reaction is faster in the presence of a heterogeneous catalyst. Explain the meaning of the term *heterogeneous* as applied to a catalyst. Draw a labelled enthalpy level diagram that shows the effect of the catalyst. [3]

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2. (a) A 25.0 cm³ sample of an aqueous solution of barium hydroxide, of concentration 0.146 mol dm⁻³ was exactly neutralized by 28.7 cm³ of aqueous nitric acid, according to the following equation.



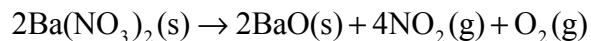
Calculate the concentration (in mol dm⁻³) of the nitric acid. [3]

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- (b) A solution containing 0.142 mol aqueous nitric acid was added to a solution containing 0.107 mol barium hydroxide. Calculate the amount (in mol) of barium nitrate formed. [1]

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- (c) A 0.010 mol sample of the barium nitrate formed was heated until it had completely decomposed according to the following equation.



Use the ideal gas equation to calculate the total volume, in cm³, of gaseous products obtained at 387 K and 1.12 × 10⁵ Pa. [3]

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3. Values of first ionization energy for the elements are shown in Table 7 of the Data Booklet.

(a) Define the term *first ionization energy* and write an equation to illustrate it, using magnesium as an example. [3]

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(b) Explain why the first ionization energy of aluminium is lower than that of magnesium. [2]

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(c) Explain why the third ionization energy of magnesium is much higher than its first ionization energy. [2]

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(d) Use the Aufbau principle to deduce the full electron configuration of cobalt. Identify the sub-level from which an electron is removed when the first ionization energy of cobalt is measured. [2]

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4. (a) Using information from Table 16 of the Data Booklet, write an equation for the dissociation of chloroethanoic acid, and calculate the pH value of a $0.200 \text{ mol dm}^{-3}$ solution of chloroethanoic acid at 298 K. [5]

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- (b) The approximate pH values of four equimolar aqueous salt solutions are shown in the following table.

Solution	A	B	C	D
pH	2	6	7	9

The solutions are listed below. Match each of the solutions with the letter (A, B, C or D) by writing the letter next to the appropriate solution. [2]

- potassium bromide
- potassium ethanoate
- iron(II) chloride
- iron(III) chloride

- (c) Give a reason for each of your choices in part (b). [4]

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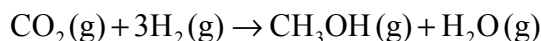


SECTION B

Answer **two** questions. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.

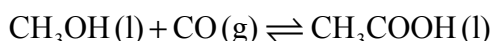
5. (a) Define the term *standard enthalpy of formation*, and write an equation to illustrate it, using methanol as your example. [4]

- (b) One reaction used in the manufacture of methanol is shown below.



Define the term *average bond enthalpy*. Using values from Table 10 of the Data Booklet, calculate the enthalpy change for this reaction. [5]

- (c) One industrial method of manufacturing ethanoic acid uses methanol as a feedstock in the following exothermic reaction.

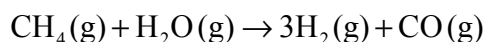


The standard enthalpy of formation of $\text{CO}(\text{g})$ is -111 kJ mol^{-1} . Using information from Table 11 of the Data Booklet, calculate the enthalpy change for the reaction above. [2]

- (d) Typical conditions used for the reaction in part (c) are 450 K and 30 atm. Use Le Chatelier's principle to predict and explain the effect on the position of equilibrium of, separately, increasing each of these values. [4]

- (e) State what is meant by the symbol ΔS^\ominus . Predict, with a reason, the sign of ΔS^\ominus for the reaction in part (c). [2]

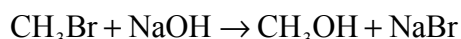
- (f) Methanol can be made from "synthesis gas", produced by the following reaction.



For this reaction, $\Delta H^\ominus = +210 \text{ kJ}$ and $\Delta S^\ominus = +216 \text{ J K}^{-1}$.

Use these values to explain why this reaction is not spontaneous at 298 K. Calculate the temperature at which it becomes spontaneous. [4]

- (g) A reaction that can be used to prepare methanol is shown in the following equation.



Give the name of the mechanism of this reaction and show the mechanism, using curly arrows to represent the movement of electron pairs. [4]



6. (a) The VSEPR theory can be used to predict the distribution of electron pairs and the shapes and bond angles of many molecules and ions. Show how this theory can be used to explain why ammonia has a tetrahedral distribution of electron pairs, a trigonal pyramidal shape and a bond angle of 107° . [3]
- (b) Apply the principles of the VSEPR theory to each of the following species, in each case predicting the shape of the electron pair distribution, the shape of the actual species and the bond angle(s).
- (i) F_2O [3]
- (ii) ICl_4^- [3]
- (c) The compound chloroethene, $CH_2=CH-Cl$, can be used to illustrate several terms used in the theory of bonding. Using this compound as the example, explain what is meant by each of the following.
- (i) Lewis structure [1]
- (ii) Sigma and pi bonds [4]
- (iii) Hybridization [2]
- (d) The carbon-chlorine bond length in chloroethene is 0.169 nm. Use information from Table 9 of the Data Booklet to explain how delocalization of electrons can occur in this molecule and suggest a value for its carbon-carbon bond length. [4]
- (e) Arrange the following compounds in order of increasing boiling point (starting with the lowest boiling point) and explain your choice by reference to the intermolecular forces involved. [5]

bromoethene

chloroethene

ethene



7. (a) Aluminium and oxygen combine together to form a compound that has a high melting point and is a good conductor of electricity when molten. Write an equation to represent the reaction and explain, in terms of its bonding and structure, why the compound has these properties. [4]
- (b) Aluminium and chlorine combine together to form a compound Al_2Cl_6 that has a low melting point and is a poor conductor of electricity when molten. Explain, in terms of its bonding and structure, why it has these properties. [3]
- (c) Describe the two different ways in which current flows during the electrolysis of molten aluminium oxide. Write an equation showing the formation of each of the products. [4]
- (d) Samples of aluminium oxide and aluminium chloride are added, with stirring, to separate beakers of pure water. Suggest the pH value of the liquid in each beaker after the stirring, giving a reason for your choice. Write an equation for any reaction occurring. [5]
- (e) A half-cell is made using an aluminium rod and an aqueous solution of aluminium sulfate. State two conditions that must apply if this half-cell is used to measure the standard electrode potential of aluminium. [2]
- (f) The cell described in part (e) is connected to a silver half-cell, both under standard conditions. Using information from Table 15 of the Data Booklet, deduce the overall equation for the reaction that occurs, and calculate the cell potential. [3]
- (g) When water reacts with zinc ions it acts as a ligand in the formation of the complex ion $[\text{Zn}(\text{H}_2\text{O})_4]^{2+}$. Explain what is meant by the term *ligand*. Explain why solutions containing this complex ion are colourless but those containing $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ are coloured. [4]



8. (a) Explain why the ^1H NMR spectrum of butane shows two peaks with areas in the ratio 3:2. [2]
- (b) Describe the structural feature responsible for optical isomerism. Outline how optical isomers can be distinguished. [3]
- (c) Alcohols can be oxidized by refluxing with hot acidified potassium dichromate(VI). State the colour change occurring when this compound acts as an oxidizing agent and the oxidation number of the chromium compound formed. [2]
- (d) There are four structural isomers of the alcohol with the formula $\text{C}_4\text{H}_9\text{OH}$. These alcohols can be distinguished using the information referred to in parts (a) to (c). The following table gives further information about these four alcohols.

Alcohol	Number of peaks in ^1H NMR spectrum	Optical isomers	Final organic oxidation product with acidified potassium dichromate(VI)
A	5	no	carboxylic acid
B	5	yes	ketone
C	4	no	carboxylic acid
D	2	no	no oxidation occurs

- Deduce the structural formula of each of the alcohols A to D. [4]
- (e) For alcohol B, draw two structures to represent the optical isomers, showing clearly the relationship between them. Write an equation for the oxidation of one of the optical isomers of B, using [O] to represent the oxidizing agent and showing the structure of the organic product. [3]
- (f) Alcohols A and C can be oxidized to different products to those named in (d) using the same oxidizing agent as in part (c). State the type of compound formed in these oxidations and describe the conditions used to obtain this type of compound. [2]
- (g) Three alkenes are formed by the dehydration of alcohols A to D. Draw the structures of these alkenes. [3]
- (h) There are three possible compounds with the molecular formula $\text{C}_3\text{H}_8\text{O}$. Two of these compounds E and F have infrared spectra that show absorption in the regions of $1000\text{--}1300\text{ cm}^{-1}$ and $3230\text{--}3550\text{ cm}^{-1}$. Use this information, and table 18 in the Data Booklet, to deduce the structures of E and F. Explain how you could distinguish between E and F. [6]

