IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M04/420/H(2)+

CHEMISTRY
HIGHER LEVEL
PAPER 2

Candidate number

Tuesday 18 May 2004 (afternoon)

2 hours 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your candidate number in the box 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 candidate 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** questions in the spaces provided.*

1. Nitrogen(II) oxide reacts with hydrogen as shown by the following equation.

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

The table below shows how the rate of reaction varies as the reactant concentrations vary.

Experiment	**Initial [NO] / mol dm^{-3}**	**Initial [H_2] / mol dm^{-3}**	**Initial rate / mol N_2 dm^{-3} s^{-1}**
1	0.100	0.100	2.53×10^{-6}
2	0.100	0.200	5.05×10^{-6}
3	0.200	0.100	10.10×10^{-6}
4	0.300	0.100	22.80×10^{-6}

(a) Determine the order of reaction with respect to NO and with respect to H_2. Explain how you determined the order for NO. *[3]*

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H_2 . . . . . .

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(b) Write the rate expression for the reaction. *[1]*

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(c) Calculate the value for the rate constant, including its units. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(d) A suggested mechanism for this reaction is as follows.

$$H_2 + NO \rightleftharpoons X \quad \text{fast step}$$
$$X + NO \rightarrow Y + H_2O \quad \text{slow step}$$
$$Y + H_2 \rightarrow N_2 + H_2O \quad \text{fast step}$$

State and explain whether this mechanism agrees with the experimental rate expression in (b). *[4]*

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(e) Explain why a single step mechanism is unlikely for a reaction of this kind. *[2]*

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(f) Deduce how the initial rate of formation of $H_2O(g)$ compares with that of $N_2(g)$ in experiment 1. Explain your answer. *[2]*

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2. 100 cm^3 of ethene, C_2H_4, is burned in 400 cm^3 of oxygen, producing carbon dioxide and some liquid water. Some oxygen remains unreacted.

(a) Write the equation for the complete combustion of ethene. *[2]*

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(b) Calculate the volume of carbon dioxide produced and the volume of oxygen remaining. *[2]*

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3. (a) Write an equation for the formation of zinc iodide from zinc and iodine. *[1]*

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(b) 100.0 g of zinc is allowed to react with 100.0 g of iodine producing zinc iodide. Calculate the amount (in moles) of zinc and iodine, and hence determine which reactant is in excess. *[3]*

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(c) Calculate the mass of zinc iodide that will be produced. *[1]*

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4. (a) Define the term *isotope*. *[2]*

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(b) A sample of gallium exists as two isotopes, ^{69}Ga, relative abundance 61.2 %, and ^{71}Ga, relative abundance 38.8 %. Calculate the relative atomic mass of gallium. *[1]*

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5. (a) Evidence for the existence of energy levels in atoms is provided by line spectra. State how a line spectrum differs from a continuous spectrum. *[1]*

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(b) On the diagram below draw **four** lines in the visible line spectrum of hydrogen. *[1]*

Low energy High energy

(c) Explain how the formation of lines indicates the presence of energy levels. *[1]*

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6. Describe in molecular terms the processes that occur when

(a) a mixture of ice and water is maintained at the melting point. *[2]*

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(b) a sample of a very volatile liquid (such as ethoxyethane) is placed on a person's skin. *[2]*

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7. The equilibrium between nitrogen dioxide (dark brown) and dinitrogen tetroxide (colourless) is represented by the following equation.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \quad \Delta H = \text{negative} \quad K_c = 1 \text{ at } 328 \text{ K}$$

(a) Write the equilibrium constant expression, K_c. *[1]*

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(b) State and explain the effect of an increase in temperature on the value of K_c. *[2]*

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(c) State and explain the visible change that takes place as a result of a decrease in pressure, after equilibrium is re-established. *[2]*

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(d) Two moles of $NO_2(g)$ and two moles of $N_2O_4(g)$ were placed in an empty 1 dm^3 container and allowed to come to equilibrium at 328 K. Predict, with reference to the value of K_c, whether the equilibrium mixture would contain more or less than two moles of $NO_2(g)$. *[2]*

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SECTION B

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

8. (a) (i) State the full electron configuration for argon. *[1]*

(ii) Give the formulas of **two** oppositely charged ions which have the same electron configuration as argon. *[2]*

(b) Draw Lewis (electron dot) structures for the following ions.

NO_2^- NO_2^+

Determine and explain the shape of each ion. *[6]*

(c) (i) List the following substances in order of increasing boiling point (lowest first).

CH_3CHO C_2H_6 CH_3COOH C_2H_5OH *[2]*

(ii) State whether each compound is polar or non-polar, and explain the order of boiling points in (c)(i). *[8]*

(d) (i) State and explain the difference in electrical conductivity of diamond and graphite. *[4]*

(ii) Outline how potassium chloride is able to act as an electrical conductor. *[2]*

9. (a) Explain in terms of $\Delta G^{\ominus}$, why a reaction for which both $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ are positive is sometimes spontaneous and sometimes not. *[4]*

(b) Consider the following reaction.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

(i) Using the average bond enthalpy values in Table 10 of the Data Booklet, calculate the standard enthalpy change for this reaction. *[4]*

(ii) The absolute entropy values, S, at 300 K for $N_2(g)$, $H_2(g)$ and $NH_3(g)$ are 193, 131 and 192 $J\,K^{-1}\,mol^{-1}$ respectively. Calculate $\Delta S^{\ominus}$ for the reaction and explain the sign of $\Delta S^{\ominus}$. *[3]*

(iii) Calculate $\Delta G^{\ominus}$ for the reaction at 300 K. *[1]*

(iv) If the ammonia were produced as a **liquid** and not as a gas, state and explain the effect this would have on the value of $\Delta H^{\ominus}$ for the reaction. *[2]*

(c) Define the term *standard enthalpy of formation*, and write the equation for the standard enthalpy of formation of ethanol. *[5]*

(d) Bond enthalpies are tabulated as *average bond enthalpies*. Explain what this term means. *[2]*

(e) Enthalpies of reactions, for example combustion, can be calculated using average bond enthalpies or enthalpies of formation. The two methods give closer results for cyclohexane than they do for benzene. Explain this difference. *[4]*

10. (a) Some standard electrode potentials are shown in Table 15 of the Data Booklet.

(i) State three conditions under which the hydrogen electrode is assigned a potential of zero. *[3]*

(ii) Calculate the cell potential of a cell made by connecting standard copper and zinc electrodes. State the direction of electron flow in the external circuit when the cell produces current. Outline the changes occurring at the electrodes and in the solutions during the process. *[5]*

(b) Using information from Table 15, determine whether or not there is a spontaneous reaction between copper metal and a solution containing hydrogen ions. *[2]*

(c) Using information from Table 15, identify a substance that will oxidize bromide ions but not chloride ions. Explain your choice, and write an equation for the redox reaction you have chosen. *[5]*

(d) A current is passed through molten sodium chloride. Identify the substance formed at each electrode and write an equation to represent the formation of each substance. Determine the mole ratio in which the substances are formed. *[5]*

(e) Sodium chloride in aqueous solution is electrolysed.

(i) Identify the substances formed, and their relative amounts, when a concentrated solution is used. *[2]*

(ii) Identify the substances formed, and their relative amounts, when a very dilute solution is used. *[2]*

(iii) Write an equation for a reaction occurring when aqueous sodium chloride, but not molten sodium chloride, is electrolysed. *[1]*

11. This question refers to the compounds in the following reaction scheme.

$$\underset{\mathbf{A}}{C_3H_7Br} \xrightarrow{NaOH} \underset{\mathbf{B}}{C_3H_8O} \xrightarrow{\text{oxidation}} \underset{\mathbf{C}}{C_3H_6O} \xrightarrow{\text{oxidation}} \underset{\mathbf{D}}{C_3H_6O_2}$$

(a) The ^{1}H NMR spectra of **C** and **D** both show three peaks with area ratios of 3:2:1. The infrared spectra of **C** and **D** both show sharp absorptions close to 1720 cm^{-1}.

(i) Explain what this spectral information indicates about the structure of **C** and **D**, and deduce their structures. *[5]*

(ii) Suggest **two** infrared ranges in which there would be absorption in the spectrum of **D** but not in that of **C**. *[2]*

(b) Deduce the structure of **B** and predict the ratio of areas under the peaks in its ^{1}H NMR spectrum. *[2]*

(c) State a suitable reagent for the oxidation of **B** to **C** and **C** to **D**. Explain how the oxidation of **B** to **C** could be achieved without further oxidation to **D**. *[3]*

(d) The conversion of **A** to **B** takes place by an S_N2 mechanism. State what is meant by the term S_N2 and describe, by using "curly arrows" to show the movement of electron pairs, the mechanism of this conversion. *[6]*

(e) Deduce how the rate of reaction of **A** with NaOH would compare with that of the compound $CH_2CH_2CH_2Cl$ with NaOH. Explain your answer by referring to Table 10 of the Data Booklet. *[2]*

(f) **B** and **D** react with each other when heated with concentrated sulfuric acid. State the name of this type of reaction and deduce the structure of the product. *[2]*

(g) Write the structure of an ester isomer of **D** and explain why it is less soluble in water than **D**. *[3]*