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

N03/420/H(2)+

**CHEMISTRY**
**HIGHER LEVEL**
**PAPER 2**

Candidate number

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Friday 7 November 2003 (afternoon)

2 hours 15 minutes

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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.** (a) Given the following data

$$\Delta H_f^{\ominus}(CF_4(g)) = -680 \text{ kJ mol}^{-1}$$
$$\text{Bond enthalpy, } F_2(g) = +158 \text{ kJ mol}^{-1}$$
$$C(s) \rightarrow C(g); \Delta H = +715 \text{ kJ mol}^{-1}$$

calculate the average bond enthalpy (in kJ $mol^{-1}$) for the C—F bond. *[4]*

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*(This question continues on the following page)*

*(Question 1 continued)*

(b) (i) For the process

$$C_6H_6(l) \rightarrow C_6H_6(s)$$

$\Delta H^{\ominus} = -9.83 \text{ kJ mol}^{-1}$ and $\Delta S^{\ominus} = -35.2 \text{ J K}^{-1} \text{ mol}^{-1}$. Predict and explain the effect of an increase in temperature on the spontaneity of the process. *[3]*

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(ii) Calculate the temperature (in °C) at which $\Delta G = 0$ for the above process and explain the significance of this temperature. *[3]*

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**2.** (a) Aqueous $XO_4^{3-}$ ions form a precipitate with aqueous silver ions, $Ag^+$. Write a balanced equation for the reaction, including state symbols. *[2]*

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(b) When $41.18\ cm^3$ of a solution of aqueous silver ions with a concentration of $0.2040\ mol\ dm^{-3}$ is added to a solution of $XO_4^{3-}$ ions, 1.172 g of the precipitate is formed.

(i) Calculate the amount (in moles) of $Ag^+$ ions used in the reaction. *[1]*

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(ii) Calculate the amount (in moles) of the precipitate formed. *[1]*

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(iii) Calculate the molar mass of the precipitate. *[2]*

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(iv) Determine the relative atomic mass of X and identify the element. *[2]*

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**3.** (a) State a physical property that is different for isotopes of an element. *[1]*

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(b) Chlorine exists as two isotopes, $^{35}Cl$ and $^{37}Cl$. The relative atomic mass of chlorine is 35.45. Calculate the percentage abundance of each isotope. *[2]*

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(c) State the complete electronic configuration of bromine, Br and the iron(III) ion, $Fe^{3+}$. *[2]*

Br: . . . . . .

$Fe^{3+}$: . . . . . .

**4.** (a) (i) Calculate the $K_a$ value of methanoic acid, HCOOH, using table 16 in the Data Booklet. *[1]*

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(ii) Based on its $K_a$ value, state and explain whether methanoic acid is a strong or weak acid. *[2]*

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(iii) Calculate the hydrogen ion concentration and the pH of a $0.010\ \text{mol dm}^{-3}$ methanoic acid solution. State **one** assumption made in arriving at your answer. *[4]*

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(b) Explain how you would prepare a buffer solution of pH3.75 starting with methanoic acid. *[3]*

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**5.** (a) When a concentrated aqueous solution of sodium chloride is electrolyzed using inert electrodes, a different gas is produced at each electrode.

(i) Write equations for the oxidation and reduction half-reactions. *[2]*

Oxidation half-reaction: . . . . . .

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Reduction half-reaction: . . . . . .

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(ii) Explain why sodium is not formed during the electrolysis of aqueous NaCl solution. *[1]*

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(b) Deduce the products formed during the electrolysis of an aqueous solution of sodium fluoride. Write an equation for the reaction at the positive electrode (the anode) and give your reasoning. *[4]*

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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.*

**6.** (a) Describe the acid-base character of the oxides of the period 3 elements Na to Ar. For aluminum oxide, write balanced equations to illustrate its acid-base character. *[4]*

(b) Outline the reasoning for the following in terms of electronic configuration:

(i) The first ionization energy of Al is lower than that of Mg. *[2]*

(ii) $V^{3+}(aq)$ is coloured and can behave as a reducing agent, whereas $Zn^{2+}(aq)$ is not coloured and does not behave as a reducing agent. *[6]*

(c) (i) Explain how the first ionization energy of K compares with that of Na and of Ar. *[3]*

(ii) Explain the differences between the atomic radii and the first ionization energies of Na and Mg. *[4]*

(iii) Explain the difference between the second ionization energies of Na and Mg. *[2]*

(d) Define the term *ligand*. $Cu^{2+}(aq)$ reacts with ammonia to form the complex ion $[Cu(NH_3)_4]^{2+}$. Explain this reaction in terms of an acid-base theory, and outline the bonding in the complex ion formed between $Cu^{2+}$ and $NH_3$. *[4]*

**7.** (a) The boiling points of the hydrides of group 6 elements increase in the order

$$H_2S < H_2Se < H_2Te < H_2O\,.$$

Explain the trend in the boiling points in terms of bonding. *[3]*

(b) Identify which of the compounds butane, chloroethane, propanone and propan-1-ol are

(i) insoluble in water and give your reasoning. *[2]*

(ii) water soluble and give your reasoning. *[2]*

(c) (i) Draw the Lewis structures for carbon monoxide, carbon dioxide and the carbonate ion. *[3]*

(ii) Identify the species with the longest carbon-oxygen bond and explain your answer. *[3]*

(iii) Draw the Lewis structure of $C1F_3$ and predict its shape. *[2]*

(d) Hydrazoic acid, $N_3H$, can be represented by two possible Lewis structures in which the atoms can be arranged as NNNH.

(i) Draw the **two** possible Lewis structures of $N_3H$. *[2]*

(ii) Predict the N—N—N and H—N—N bond angles in each case and give your reasoning. *[6]*

(iii) Predict the hybridization of the N atom bonded to the hydrogen atom in each case. *[2]*

**8.** (a) The following data were obtained for the reaction of nitrogen monoxide gas, NO(g), with oxygen gas to form nitrogen dioxide gas, $NO_2(g)$, at $25\,^{\circ}C$.

| **Experiment** | **[NO] / mol dm$^{-3}$** | **[$O_2$] / mol dm$^{-3}$** | **Initial rate / mol dm$^{-3}$ s$^{-1}$** |
|---|---|---|---|
| 1 | 0.50 | 0.20 | $3.0\times10^{-3}$ |
| 2 | 0.50 | 0.40 | $6.0\times10^{-3}$ |
| 3 | 1.00 | 0.80 | $4.8\times10^{-2}$ |

(i) Calculate the order with respect to the two reactants and write the rate expression for the reaction. Show your reasoning. *[5]*

(ii) Explain why the following mechanism is **not** consistent with the rate expression. *[2]*

$$NO(g) + O_2(g) \rightarrow NO_2(g) + O(g); \text{ slow step}$$
$$NO(g) + O(g) \rightarrow NO_2(g); \text{ fast step}$$

(iii) Explain why the following mechanism is consistent with the rate expression, **but** is unlikely. *[2]*

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

(iv) Explain why the following mechanism is consistent with the rate expression. *[3]*

$$NO(g) + O_2(g) \rightarrow NO_3(g); \text{ fast}$$
$$NO_3(g) + NO(g) \rightarrow 2NO_2(g); \text{ slow}$$

(v) Suggest, giving a reason, **one** other mechanism that would be consistent with the rate expression. *[3]*

(b) The following equilibrium is established at $1700\,^{\circ}C$.

$$CO_2(g) + H_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

If only carbon dioxide gas and hydrogen gas are present initially, sketch on a graph a line representing rate against time for

- the forward reaction
- the reverse reaction until shortly after equilibrium is established.

Explain the shape of each line. *[7]*

(c) $K_c$ for the equilibrium reaction is determined at two different temperatures. At $850\,^{\circ}C$, $K_c = 1.1$ whereas at $1700\,^{\circ}C$, $K_c = 4.9$.

On the basis of these $K_c$ values explain whether the reaction is exothermic or endothermic. *[3]*

**9.** (a) (i) List **three** characteristics of an homologous series, and explain the term *functional group*. *[3]*

(ii) Ethanol and ethanoic acid can be distinguished by their melting points. State and explain which of the two compounds will have a higher melting point. *[2]*

(iii) Draw the **four** structures of alcohols of formula $C_4H_9OH$. Identify the structure that exists as optical isomers and give a reason for your answer. *[4]*

(b) (i) Ethanoic acid reacts with ethanol in the presence of concentrated sulfuric acid and heat. Identify the type of reaction that takes place. Write an equation for the reaction, name the organic product and draw its structure. *[4]*

(ii) State and explain the role of sulfuric acid in this reaction. *[2]*

(iii) Explain what happens if the organic product in (b) (i) is heated with water and sulfuric acid. *[1]*

(iv) Explain why the reaction goes to completion when the organic product is heated with aqueous sodium hydroxide. Give a balanced equation for this reaction. *[2]*

(c) For the compounds $HCOOCH_2CH_3$ and $HCOOCHCH_2$
I II

(i) state and explain which of the two compounds can react readily with bromine. *[2]*

(ii) suggest how the infrared spectra and NMR spectra would be different for the two compounds. *[3]*

(iii) compound II can form polymers. State the type of polymerization compound II undergoes and draw the structure of the repeating unit of the polymer. *[2]*