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

M07/4/CHEMI/HP2/ENG/TZ0/XX

22076102

CHEMISTRY
HIGHER LEVEL
PAPER 2

Thursday 10 May 2007 (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.

0112

SECTION A

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

1. Nitrogen(II) oxide reacts with bromine according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H = \text{negative}$$

The data below were obtained for the reaction between NO(g) and $Br_2(g)$ at a specified temperature and pressure.

Experiment	Initial [NO] / mol dm^{-3}	Initial [Br_2] / mol dm^{-3}	Initial rate / mol $dm^{-3}s^{-1}$
1	2.00×10^{-2}	5.00×10^{-3}	3.20×10^{-3}
2	2.00×10^{-2}	2.50×10^{-3}	1.60×10^{-3}
3	4.00×10^{-2}	5.00×10^{-3}	1.30×10^{-2}

(a) Determine, giving a reason, the order of reaction with respect to NO and the order of reaction with respect to Br_2. *[2]*

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(b) Derive the rate expression for the reaction between NO and Br_2. *[1]*

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(c) Calculate the rate constant for the rate expression using experiment 1 and state its units. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(d) If the total volume of the reaction mixture was doubled at constant temperature, state the effect, if any, on

(i) the rate constant. *[1]*

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(ii) the rate of change of the $Br_2(g)$ concentration. *[1]*

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(e) A heterogeneous catalyst may be used in this reaction. Outline how *heterogeneous catalysts* work. *[2]*

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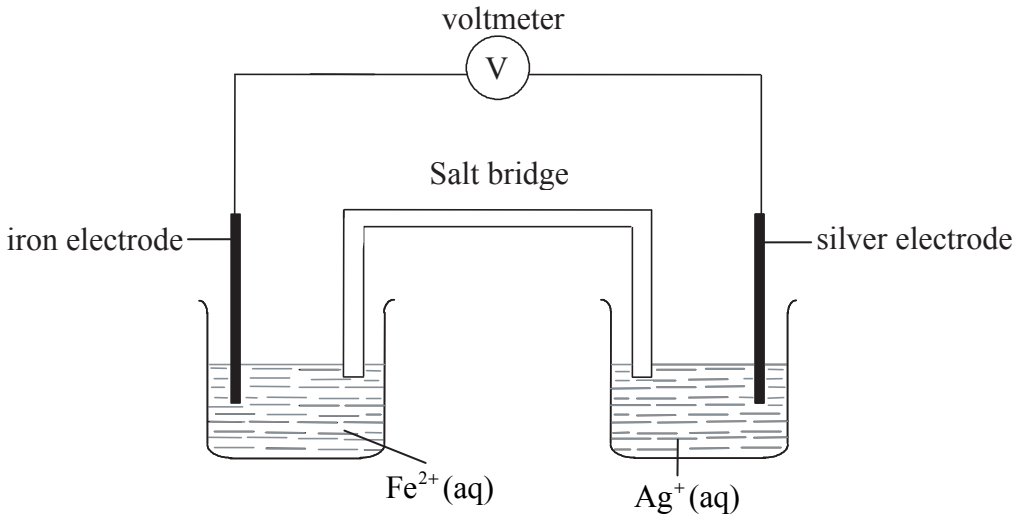
(f) Draw a labelled enthalpy level diagram for the reaction between NO(g) and $Br_2(g)$, with and without the use of a catalyst. *[3]*

2. The following diagram shows a voltaic cell.



(a) State an equation to represent the spontaneous reaction occurring in the cell. *[1]*

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(b) Define the term *standard electrode potential*. *[1]*

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(c) Use Table 15 from the Data Booklet to calculate the standard cell potential for the spontaneous reaction in (a). *[1]*

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(d) Draw arrows on the above diagram to indicate the direction of electron flow. *[1]*

3. Tin(II) ions can be oxidized to tin(IV) ions by acidified potassium permanganate(VII) solution according to the following unbalanced equation.

$$\_\_\,Sn^{2+} + \_\_\,MnO_4^- + \_\_\,H^+ \rightarrow \_\_\,Sn^{4+} + \_\_\,Mn^{2+} + \_\_\,H_2O$$

(a) Identify the oxidizing agent and the reducing agent. *[1]*

Oxidizing agent . . . . . .

Reducing agent . . . . . .

(b) Balance the equation above. *[1]*

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4. (a) Propane and oxygen react according to the following equation.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

Calculate the volume of carbon dioxide and water vapour produced and the volume of oxygen remaining, when 20.0 dm^3 of propane reacts with 120.0 dm^3 of oxygen. All gas volumes are measured at the same temperature and pressure. *[3]*

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(b) State and explain what would happen to the pressure of a given mass of gas when its absolute temperature and volume are both doubled. *[3]*

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(Question 4 continued)

(c) (i) Crocetin consists of the elements carbon, hydrogen and oxygen. Determine the empirical formula of crocetin, if 1.00 g of crocetin forms 2.68 g of carbon dioxide and 0.657 g of water when it undergoes complete combustion. *[6]*

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(ii) Determine the molecular formula of crocetin given that 0.300 mole of crocetin has a mass of 98.5 g. *[2]*

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5. Propanoic acid is classified as a weak acid.

(a) State the meaning of the term *weak acid*. *[1]*

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(b) State an equation for the reaction of propanoic acid with water. Identify **one** conjugate *Brønsted-Lowry* pair. *[2]*

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(c) State, giving a reason in each case, **two** methods other than measuring pH, that could be used to distinguish between 0.100 mol dm^{-3} propanoic acid and 0.100 mol dm^{-3} nitric acid. *[2]*

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(d) With reference to Table 16 in the Data Booklet, determine the pH of a 0.100 mol dm^{-3} solution of propanoic acid. *[3]*

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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.*

6. Consider the following reaction where colourless bromide ions react with colourless hydrogen peroxide to form a red-brown bromine solution.

$$2Br^-(aq) + H_2O_2(aq) + 2H^+(aq) \rightleftharpoons Br_2(aq) + 2H_2O(l) \qquad \Delta H = \text{negative}$$

(a) Predict and explain the effect on the **position of equilibrium** when

(i) a small amount of sodium bromide solution is added. *[2]*

(ii) a small amount of sodium hydroxide solution is added. *[2]*

(iii) a catalyst is added. *[2]*

(b) State and explain the effect on the value of the **equilibrium constant** when the temperature of the reaction is increased. *[2]*

(c) State and explain the colour change when hydrochloric acid is added to the reaction solution at equilibrium. *[3]*

(d) Define the term *standard enthalpy change of formation*, $\Delta H_f^{\ominus}$. *[2]*

(e) (i) Use the information in the following table to calculate the enthalpy change for the complete combustion of but-1-ene according to the following equation. *[3]*

$$C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$$

Compound	$C_4H_8(g)$	$CO_2(g)$	$H_2O(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	+ 1	– 394	– 242

(ii) Deduce, giving a reason, whether the reactants or the products are more stable. *[2]*

(iii) Predict, giving a reason, how the enthalpy change for the complete combustion of but-2-ene would compare with that of but-1-ene based on average bond enthalpies. *[1]*

(This question continues on the following page)

(Question 6 continued)

(f) Using the data below,

Compound	$C_4H_8(g)$	$CO_2(g)$	$H_2O(g)$	$O_2(g)$
$S^{\ominus}$ / J K^{-1} mol^{-1}	306	214	189	205

calculate for the reaction in (e) at 25 °C

(i) the standard entropy change, $\Delta S^{\ominus}$. *[2]*

(ii) the standard free energy change, $\Delta G^{\ominus}$. *[2]*

(g) Predict, giving a reason, the spontaneity of the reaction in (e)(i) at both high and low temperatures. *[2]*

7. (a) Draw the Lewis structures, state the shapes and predict the bond angles for the following species.

(i) PCl_5 *[3]*

(ii) SCl_2 *[3]*

(iii) ICl_4^- *[3]*

(b) Use the information in the table below to identify the type of bonding and structure in each of the following substances. Explain these properties in terms of bonding and structure. *[6]*

Substance	Melting point / K	Electrical conductivity
A	1986	Does not conduct in any state.
B	1074	Conducts only in the liquid state and aqueous solution.

(c) (i) State the meaning of the term *hybridization*. *[1]*

(ii) State the type of hybridization around the carbon atoms in C_{60} fullerene, diamond and graphite. *[3]*

(iii) Explain why graphite and C_{60} fullerene can conduct electricity. *[2]*

(d) (i) Compare how atomic orbitals overlap in the formation of sigma (σ) and pi (π) bonds. *[2]*

(ii) State the number of sigma bonds and pi bonds in $H_2CC(CH_3)CHCH_2$. *[2]*

8. (a) Describe the following stages in the operation of the mass spectrometer.

(i) ionization *[2]*

(ii) deflection *[2]*

(iii) acceleration *[1]*

(b) (i) State the meaning of the term *isotopes* of an element. *[1]*

(ii) Calculate the percentage abundance of the two isotopes of rubidium ^{85}Rb and ^{87}Rb. *[2]*

(iii) State **two** physical properties that would differ for each of the rubidium isotopes. *[1]*

(iv) Determine the full electron configuration of an atom of Si, an Fe^{3+} ion and a P^{3-} ion. *[3]*

(c) (i) State the meaning of the term *electronegativity* and explain why the noble gases are not assigned electronegativity values. *[2]*

(ii) State and explain the trend in electronegativity across period 3 from Na to Cl. *[2]*

(iii) Explain why Cl_2 rather than Br_2 would react more vigorously with a solution of I^-. *[2]*

(d) State the acid-base properties of the following period 3 oxides.

$$MgO \quad Al_2O_3 \quad P_4O_6$$

Write equations to demonstrate the acid-base properties of each compound. *[7]*

9. Ethene is an unsaturated hydrocarbon used as a starting material for many organic chemicals.

(a) State the meaning of the term *unsaturated hydrocarbon*. *[1]*

(b) State an equation for the conversion of ethene to ethanol and identify the type of reaction. *[2]*

(c) Describe the complete oxidation of ethanol. Include the conditions, reagents required and any colour changes. Name the organic product **X**. *[4]*

(d) State an equation for the reaction between ethanol and compound **X**. Include any other reagent required. Name the organic compound **Z** and state **one** use of this product. *[4]*

(e) For compounds **X** and **Z**, use Table 18 in the Data Booklet to identify **one** similar and **two** different absorption bands in their infrared spectra. *[3]*

(f) Ethanol can also undergo partial oxidation to form compound **Y**. Name compound **Y**. For compounds **X** and **Y**, use Table 19 in the Data Booklet to identify **one** similarity and **one** difference in their respective ^{1}H NMR spectra. Do **not** consider splitting patterns in your answer. *[3]*

(g) (i) State the meaning of the term *isomers*. *[1]*

(ii) Draw the functional group isomers of C_3H_6O. *[2]*

(iii) State the meaning of the term *optical isomers*. Draw the alcohol with the molecular formula $C_4H_{10}O$ which exhibits optical isomerism and identify the chiral carbon atom. *[3]*

(iv) Other than the optical isomers in (g) (iii), draw the other **three** alcohol isomers of molecular formula $C_4H_{10}O$ and identify the isomer that does not undergo oxidation. *[2]*