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

N06/4/CHEMI/HP2/ENG/TZ0/XX

88066102

CHEMISTRY
HIGHER LEVEL
PAPER 2

Wednesday 8 November 2006 (afternoon)

2 hours 15 minutes

Candidate session number

0	0							

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. (a) An organic compound **A** contains 62.0 % by mass of carbon, 24.1 % by mass of nitrogen, the remainder being hydrogen.

(i) Determine the percentage by mass of hydrogen and the empirical formula of **A**. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) Define the term *relative molecular mass*. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iii) The relative molecular mass of **A** is 116. Determine the molecular formula of **A**. *[1]*

. . . . . .

. . . . . .

(b) A molecule of **A** contains an NH_2 group at each end of a hydrocarbon chain.

(i) Draw a structural formula to represent a molecule of **A**. Include any lone pairs of electrons in your structure. *[1]*

(ii) Predict the C–N–H bond angle in **A** and explain why it is different from the C–C–N bond angle. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

2. Methylamine can be manufactured by the following reaction.

$$CH_3OH(g) + NH_3(g) \rightarrow CH_3NH_2(g) + H_2O(g)$$

(a) Define the term *standard enthalpy change of formation.* *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The values of standard enthalpy changes of formation for some compounds are shown in the table.

Compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$NH_3(g)$	-46
$H_2O(g)$	–242

Predict, with a reason, whether the value of $\Delta H_f^\ominus$ for $H_2O(l)$ is less than, greater than, or equal to, the value of $\Delta H_f^\ominus$ for $H_2O(g)$. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Use information from the table in (b) and from Table 11 of the Data Booklet to calculate the enthalpy change for the reaction used to manufacture methylamine. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 2 continued)

(d) In the manufacturing process 2000 kg of each reactant are mixed together.

(i) Identify the limiting reactant, showing your working. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) Calculate the maximum mass, in kg, of methylamine that can be obtained from this mixture of reactants. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

3. (a) Explain the meaning of the term *hybridization*. *[1]*

. . . . . .

. . . . . .

(b) State the type of hybridization shown by the carbon atom in the H–C≡N molecule, and the number of σ and π bonds present in the C≡N bond. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Describe how σ and π bonds form. *[4]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

4. Butane and but-2-ene react with bromine in different ways.

(a) (i) Write an equation for the reaction between butane and bromine, showing the structure of a possible organic product. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) Identify the type of bond fission that occurs in bromine and the species that reacts with butane. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) (i) Write an equation for the reaction between but-2-ene and bromine, showing the structure of the organic product. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) State the type of reaction occurring. *[1]*

. . . . . .

. . . . . .

(This question continues on the following page)

(Question 4 continued)

(c) The enthalpies of hydrogenation of but-2-ene and benzene are shown below.

Compound	$\Delta H^{\ominus}$ (hydrogenation) / kJ mol^{-1}
but-2-ene	–120
benzene	–208

Predict the value of $\Delta H^{\ominus}$ (hydrogenation) that benzene would have if it contained the same type of bonding as but-2-ene. State what can be deduced from the difference in these two values for benzene. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

5. Some vaporized magnesium is introduced into a mass spectrometer. One of the ions that reaches the detector is $^{25}Mg^{+}$.

(a) Identify the number of protons, neutrons and electrons in the $^{25}Mg^{+}$ ion. *[1]*

. . . . . .

. . . . . .

(b) State how this ion is accelerated in the mass spectrometer. *[1]*

. . . . . .

. . . . . .

(c) The $^{25}Mg^{2+}$ ion is also detected in this mass spectrometer by changing the magnetic field. Deduce and explain, by reference to the *m*/*z* values of these two ions of magnesium, which of the ions $^{25}Mg^{2+}$ and $^{25}Mg^{+}$ is detected using a stronger magnetic field. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

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. (a) Magnesium chloride and silicon(IV) chloride have very different properties.

(i) Give the formula and physical state at room temperature of each chloride. *[2]*

(ii) State the conditions under which, if at all, each chloride conducts electricity. *[2]*

(iii) Each chloride is added to water in separate experiments. Suggest an approximate pH value for the solution formed, and write an equation for any reaction that occurs. *[3]*

(b) The elements in the d-block in the periodic table have several characteristics in common.

(i) Give the electronic configuration of Ni^{2+}. *[1]*

(ii) Explain what is meant by a ligand, and describe the type of bond formed between a ligand and a d-block element. *[2]*

(iii) Determine the oxidation numbers of copper in the species

$$[Cu(NH_3)_4]^{2+} \text{ and } [CuCl_4]^{2-}$$ *[2]*

(iv) Explain why the species in (b)(iii) are coloured. *[3]*

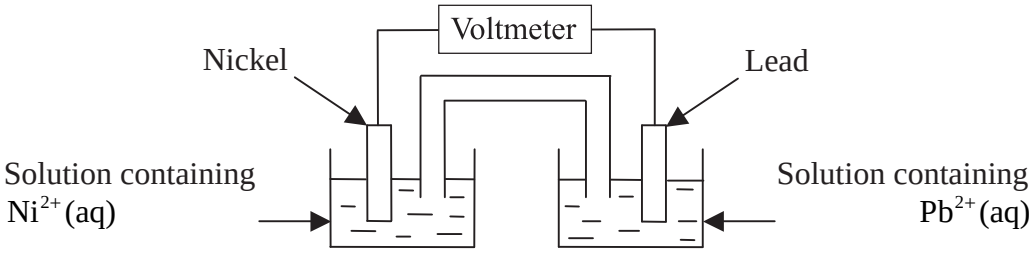
(v) Identify the d-block element used as a catalyst in the Haber process and write an equation for the reaction occurring. *[2]*

(This question continues on the following page)

(Question 6 continued)

(c) Use information from Table 15 of the Data Booklet, where relevant, in answering this part.

(i) The diagram shows the apparatus used in an experiment involving half-cells.



The reading on the voltmeter is 0.10 V. State **two** standard conditions that apply for this reading to be obtained. *[2]*

(ii) The voltmeter is replaced by a 2 volt power supply, so that non-spontaneous reactions occur. Deduce the half-equations for these reactions. *[2]*

(iii) Chlorine gas is formed when potassium manganate(VII) is added to concentrated hydrochloric acid. Calculate the cell potential for this reaction and deduce the equation for the reaction. *[3]*

(iv) Explain why potassium dichromate(VI) does not react with concentrated hydrochloric acid. *[1]*

7. (a) Three organic compounds have the same M_r values.

CH_3CH_2COOH $CH_3CH_2OCH_2CH_3$ $CH_3CH_2CH_2CH_2OH$

(i) State and explain which compound has the lowest boiling point. *[2]*

(ii) Calculate the volume that 0.0200 mol of the gaseous compound in (a)(i) would occupy at 70 °C and 1.10×10^5 Pa . *[3]*

(iii) All three compounds show absorptions in their infrared spectra corresponding to C–C and C–H bonds. Identify **one** other bond that is present in all three compounds. *[1]*

(iv) The mass spectra of all three compounds contain peaks at *m*/*z* values of 45. Deduce the structures of the three different fragment ions responsible for these peaks. *[3]*

(b) CH_3COCH_3 can be prepared in the laboratory from an alcohol. State the name of this alcohol, the type of reaction occurring and the reagents and conditions needed for the reaction. *[5]*

(c) Explain why butan-2-ol, $CH_3CH(OH)CH_2CH_3$, exists as *enantiomers*, and describe how pure samples of the enantiomers can be distinguished experimentally. *[3]*

(d) Butan-2-ol can be dehydrated to form two different alkenes, **B** and **C**. The ^{1}H NMR spectrum of **B** contains two peaks with areas in the ratio 3:1.

(i) Identify alkene **B**. *[1]*

(ii) Predict the peak area ratio in the ^{1}H NMR spectrum of alkene **C**. *[1]*

(e) 2-bromobutane can be converted into butan-2-ol by a nucleophilic substitution reaction. This reaction occurs by two different mechanisms.

(i) Give the structure of the transition state formed in the S_N2 mechanism. *[2]*

(ii) Write equations for the S_N1 mechanism. *[2]*

(f) State and explain whether the rate of the S_N1 mechanism will decrease, increase or remain the same, if 2-chlorobutane is used instead of 2-bromobutane. *[2]*

8. (a) The equation for a reaction used in industry is

$$CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g) \quad \Delta H^{\ominus} = +210 \text{ kJ}$$

Deduce the equilibrium constant expression, K_c, for this reaction. *[1]*

(b) Use Le Chatelier's principle to predict the effect of each of the following changes on the position of equilibrium and the value of K_c for the reaction in (a).

(i) Increasing the temperature at constant pressure. *[2]*

(ii) Increasing the pressure at constant temperature. *[2]*

(c) The equation for another reaction used in industry is

$$CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g) \quad \Delta H^{\ominus} = -42 \text{ kJ}$$

(i) Under certain conditions of temperature and pressure, 2.0 mol of carbon monoxide and 3.2 mol of steam were left to reach equilibrium. At equilibrium, 1.6 mol of both hydrogen and carbon dioxide were present.
Calculate the amounts of carbon monoxide and steam at equilibrium and the value of K_c. *[3]*

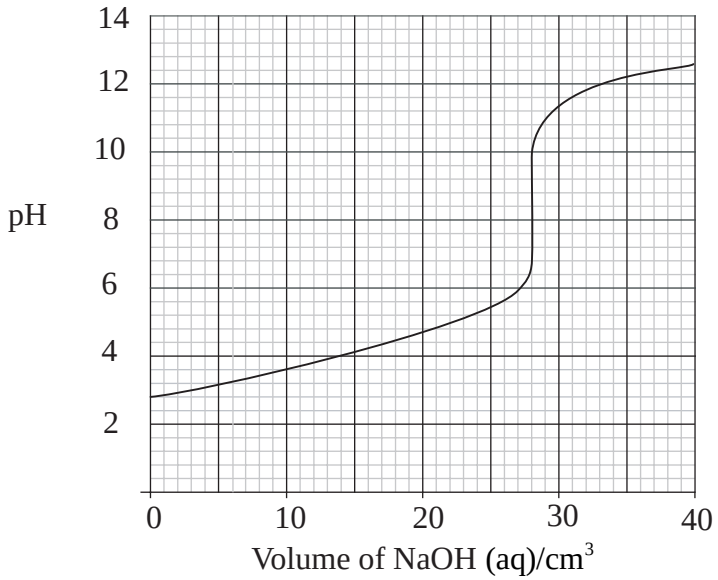
(ii) Under the same conditions of temperature and pressure, 2.0 mol of carbon monoxide and 2.0 mol of steam were left to reach equilibrium.
Calculate the amounts of each reactant and product at equilibrium.
(If you were unable to calculate a value for K_c in (c)(i) use the value 9.0, although this is not the correct value.) *[2]*

(d) Many reversible reactions in industry use a catalyst. State and explain the effect of a catalyst on the position of equilibrium and the value of K_c. *[4]*

(This question continues on the following page)

(Question 8 continued)

(e) A titration was carried out to determine the concentration of 25.0 cm^3 of an aqueous solution of ethanoic acid. The pH value of the liquid in the flask was measured during the titration. The results are shown on the graph below.



(i) Use the graph to determine the values of pH and $[H^+]$ of the ethanoic acid solution. *[2]*

(ii) Use the graph to determine the volume of 0.100 $mol\ dm^{-3}$ sodium hydroxide solution needed to exactly neutralize the ethanoic acid. *[1]*

(iii) Calculate the concentration, in $mol\ dm^{-3}$, of the ethanoic acid. *[2]*

(iv) Identify an indicator that could be used to detect the equivalence point of the titration. Using the formula HIn to represent the indicator, explain why the indicator changes colour during the titration. *[3]*

(f) The solution formed when the ethanoic acid is exactly half neutralized can act as a buffer solution.

(i) Using information from Table 16 of the Data Booklet, calculate the value of $[H^+]$ in this buffer solution, showing your working. *[2]*

(ii) Write an equation to show the buffer action of this solution when a small amount of acid is added. *[1]*

9. (a) The compound iodine chloride, ICl, reacts with hydrogen to form iodine and hydrogen chloride.

(i) Deduce the equation for this reaction. *[1]*

(ii) The kinetics of this reaction were studied at a certain temperature, when all the reactants and products were in the gas phase. The table shows the initial rate of reaction for different concentrations of reactants.

Experiment	[ICl] / mol dm^{-3}	[H_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.100	0.0500	5.00×10^{-3}
2	0.200	0.0500	1.00×10^{-2}
3	0.200	0.0250	2.50×10^{-3}

Deduce and explain the order of reaction with respect to ICl and to H_2. *[4]*

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

(iv) Use information from Experiment 1 to determine the value, with units, of the rate constant for the reaction. *[2]*

(v) Determine the rate of reaction when the concentrations of reactants in Experiment 1 are both doubled. *[1]*

(b) The overall equation for a reaction that occurs in two steps is

$$P + 2Q \rightarrow R$$

The rate expression for the reaction is

$$\text{rate} = k[P][Q]$$

(i) Suggest a mechanism for this reaction and identify the rate-determining step. *[2]*

(ii) Deduce the molecularity of the reaction. *[1]*

(c) In a first order reaction it takes four minutes for the concentration of a reactant to decrease from 0.08 mol dm^{-3} to 0.04 mol dm^{-3}. Deduce the time for the concentration to decrease from 0.04 mol dm^{-3} to 0.02 mol dm^{-3}. *[1]*

(This question continues on the following page)

(Question 9 continued)

(d) The variation of the rate constant, *k*, for a reaction with temperature is shown by the Arrhenius equation. Two versions of this equation are shown in Table 1 of the Data Booklet.

(i) Explain the significance of the Arrhenius constant, *A*, in this equation. *[1]*

(ii) Explain what is meant by the term *activation energy*, E_a. *[1]*

(iii) Describe how, using a graphical method, values of *A* and E_a can be obtained for a reaction. *[5]*

(e) The equation for a reaction used in industry is

$$CH_2CH_2 + Cl_2 \rightarrow CH_2ClCH_2Cl \qquad \Delta H^{\ominus} = -185\ \text{kJ}$$

Iron(III) chloride can be used as a catalyst for the reaction.

(i) Explain the difference between the terms *homogeneous* and *heterogeneous* when applied to a catalyst. *[1]*

(ii) Draw an enthalpy level diagram for this reaction, including labels for $\Delta H^{\ominus}$, E_a and the activation energy when a catalyst is used, E_{cat}. *[4]*