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

M05/4/CHEMI/HP2/ENG/TZ0/XX+

22056102

CHEMISTRY
HIGHER LEVEL
PAPER 2

Wednesday 4 May 2005 (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. The standard enthalpy change for the combustion of phenol, $C_6H_5OH(s)$, is $-3050\ kJ\ mol^{-1}$ at 298 K.

(a) Write an equation for the complete combustion of phenol. *[1]*

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(b) The standard enthalpy changes of formation of carbon dioxide, $CO_2(g)$, and of water, $H_2O(l)$, are $-394\ kJ\ mol^{-1}$ and $-286\ kJ\ mol^{-1}$ respectively.
Calculate the standard enthalpy change of formation of phenol, $C_6H_5OH(s)$. *[3]*

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(c) The standard entropy change of formation, $\Delta S^{\ominus}$, of phenol, $C_6H_5OH(s)$ at 298 K is $-385\ J\ K^{-1}\ mol^{-1}$. Calculate the standard free energy change of formation, $\Delta G^{\ominus}$, of phenol at 298 K. *[3]*

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(This question continues on the following page)

(Question 1 continued)

(d) Determine whether the reaction is spontaneous at 298 K, and give a reason. *[2]*

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(e) Predict the effect, if any, of an increase in temperature on the spontaneity of this reaction. *[2]*

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2. The percentage composition by mass of a hydrocarbon is C = 85.6 % and H = 14.4 %.

(a) Calculate the empirical formula of the hydrocarbon. *[2]*

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(b) A 1.00 g sample of the hydrocarbon at a temperature of 273 K and a pressure of 1.01×10^5 Pa (1.00 atm) has a volume of 0.399 dm^3.

(i) Calculate the molar mass of the hydrocarbon. *[2]*

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(ii) Deduce the molecular formula of the hydrocarbon. *[1]*

(c) Explain why the **incomplete** combustion of hydrocarbons is harmful to humans. *[2]*

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3. When a small quantity of a strongly smelling gas such as ammonia is released into the air, it can be detected several metres away in a short time.

(a) Use the kinetic molecular theory to explain why this happens. *[2]*

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(b) State and explain how the time taken to detect the gas changes when the temperature is increased. *[2]*

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4. The following reaction

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$

is described as first order with respect to N_2O_5.

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

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(b) One possible mechanism for this reaction is given below.

$$N_2O_5(g) \rightarrow NO_2(g) + NO_3(g) \qquad \text{Step 1}$$
$$N_2O_5(g) + NO_3(g) \rightarrow 2NO_2(g) + O_2(g) \qquad \text{Step 2}$$

Describe the rate expression that would result if the rate determining step in the mechanism is

(i) Step 1. *[1]*

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(ii) Step 2. *[2]*

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Outline your reasonsing.

(c) Explain what is meant by the term *half-life* for this reaction. *[1]*

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(d) State what is characteristic about the half-life of a first order reaction. *[1]*

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5. (a) Give the structural formulas of the **four** isomers of molecular formula C_4H_9Cl. State the name of each one and classify it as primary, secondary, or tertiary. *[8]*

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(b) Each of the isomers reacts with aqueous sodium hydroxide. State what class of compound is produced by this reaction. *[1]*

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(c) (i) Identify the type of isomer (primary, secondary or tertiary) which will react with aqueous sodium hydroxide almost exclusively by an S_N1 mechanism. State the meaning of the symbols in the term S_N1 mechanism. *[2]*

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(ii) Using the formula RCl to represent a chloroalkane, write an equation for the rate determining step of this reaction. *[1]*

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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. An experiment was carried out to determine the concentration of an aqueous solution of ammonia by titrating it with a solution of sulfuric acid of concentration $0.150\ \text{mol dm}^{-3}$. It was found that $25.0\ \text{cm}^3$ of the ammonia solution required $20.1\ \text{cm}^3$ of the sulfuric acid solution for neutralization.

(a) Write the equation for the reaction and calculate the concentration, in mol dm^{-3}, of the ammonia solution. *[4]*

(b) Several acid-base indicators are listed in Table 17 of the Data Booklet. State and explain which one of the following indicators should be used for this experiment: bromocresol green, phenol red or phenolphthalein. *[3]*

(c) Determine the pOH of a solution with an ammonia concentration of $0.121\ \text{mol dm}^{-3}$. ($\text{p}K_\text{b}$ of ammonia is 4.75.) *[4]*

(d) (i) State what is meant by the term *buffer solution*, and describe the composition of an acid buffer solution in general terms. *[3]*

(ii) Calculate the pH of a mixture of $50\ \text{cm}^3$ of ammonia solution of concentration $0.10\ \text{mol dm}^{-3}$ and $50\ \text{cm}^3$ of hydrochloric acid solution of concentration $0.050\ \text{mol dm}^{-3}$. *[4]*

(e) Choosing suitable examples from the following:

$$\text{NH}_3,\ \text{O}^{2-},\ \text{Cu}^{2+},\ \text{OH}^-,\ \text{NH}_2^-,\ \text{H}_2\text{O}$$

explain, using a different equation in each case, the meaning of the terms below.

(i) Brønsted-Lowry acid *[2]*

(ii) Lewis acid *[2]*

(iii) conjugate acid-base pair (Identify each member of both acid-base pairs.) *[3]*

7. (a) The letters **W**, **X**, **Y** and **Z** represent four consecutive elements in the periodic table. The number of electrons in the highest occupied energy levels are:

W: 3, **X**: 4, **Y**: 5, **Z**: 6

Write the formula for

(i) an ionic compound formed from **W** and **Y**, showing the charges. *[2]*

(ii) a covalent compound containing **X** and **Z**. *[1]*

(b) Outline the principles of the valence shell electron pair repulsion (VSEPR) theory. *[3]*

(c) For the following compounds

PCl_3 , PCl_5 , $POCl_3$

(i) Draw a Lewis structure for each molecule in the gas phase. (Show all non-bonding electron pairs.) *[3]*

(ii) State the shape of each molecule and predict the bond angles. *[6]*

(iii) Deduce whether or not each molecule is polar, giving a reason for your answer. *[3]*

(d) (i) Explain the meaning of the term *hybridization*. *[1]*

(ii) Discuss the bonding in the molecule CH_3CHCH_2 with reference to

- the formation of σ and π bonds
- the length and strength of the carbon-carbon bonds
- the types of hybridization shown by the carbon atoms *[6]*

8. (a) For the elements of period 3 (Na to Ar), state and explain

(i) the general trend in ionization energy *[2]*

(ii) any exceptions to the general trend. *[4]*

(b) Explain the following features of the melting points of the period 3 elements. Refer to bonding and structure, and use information from Table 6 in the Data Booklet.

(i) The difference between the values for sodium and magnesium *[3]*

(ii) The high value for silicon *[2]*

(iii) The difference between the values for chlorine and argon *[2]*

(c) By reference to the structure and bonding in the compounds NaCl and $SiCl_4$

(i) state and explain the differences in conductivity in the liquid state. *[3]*

(ii) predict an approximate pH value for a solution formed by adding each compound separately to water. *[4]*

(d) Two characteristics of the d-block (transition) elements are that they exhibit variable oxidation states and form coloured compounds.

(i) State **two** possible oxidation states for iron and explain these in terms of electron arrangements. *[2]*

(ii) Explain why many compounds of d-block (transition) elements are coloured. *[3]*

9. Some organic compounds can undergo dehydration.

(a) State what is meant by the term *dehydration* and give an example of a dehydrating agent. *[2]*

(b) Two of the isomers of molecular formula C_3H_8O can be dehydrated to form a compound of molecular formula C_3H_6. Give the structural formulas and the names of these three compounds. *[5]*

(c) (i) State the number of peaks and the ratio of their areas in the ^1H NMR spectra of C_3H_6 and **one** of the isomers of C_3H_8O. *[4]*

(ii) Use Table 18 in the Data Booklet to identify a strong absorption in the infrared spectrum of C_3H_8O which is not present in C_3H_6, and a strong absorption in C_3H_6 which is not present in C_3H_8O. In each case, state the absorption range and the bond responsible. *[2]*

(d) (i) The compound C_3H_6 can react with bromine. Write an equation for this reaction and name the product. State a visible change which accompanies the reaction. *[3]*

(ii) Give the full structural formula of the product formed in part (d) (i), and identify, by using an asterisk (*), a chiral carbon atom. State what distinctive property a chiral carbon atom gives to a molecule. *[2]*

(e) Name the type of polymerization reaction which C_3H_6 undergoes and draw the structure of a section of the polymer chain formed from three monomer molecules. *[2]*

(f) One of the isomers of formula C_3H_8O can be oxidized to form two different organic products, depending on the conditions used. Identify an appropriate oxidizing agent. Give structures for the two products and specify the conditions required for the formation of each. *[5]*