INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

CHEMISTRY
HIGHER LEVEL
PAPER 2

Tuesday 13 November 2001 (afternoon)

2 hours 15 minutes

Name

Number

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and 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 in a continuation answer booklet, and indicate the number of booklets used in the box below. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.
- At the end of the examination, indicate the numbers of the Section B questions answered in the boxes below.

QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/40	/40	/40
SECTION B QUESTION QUESTION		 /25 /25	 /25 /25	 /25 /25
NUMBER OF CONTINUATION BOOKLETS USED	. . . .	TOTAL /90	TOTAL /90	TOTAL /90

SECTION A

*Candidates must answer **all** questions in the spaces provided.*

In order to receive full credit in Section A, the method used and the steps involved in arriving at your answer must be shown clearly. It is possible to receive partial credit but, without your supporting work, you may receive little credit. For numerical calculations, you are expected to pay proper attention to significant figures.

1. The standard enthalpy of combustion, $\Delta H_c^\ominus$, and the relative molecular masses, M_r, of a series of alkanols are given below:

Alkanol	CH_3OH methanol	CH_3CH_2OH ethanol	$CH_3CH_2CH_2OH$ propan-1-ol	$CH_3CH_2CH_2CH_2OH$ butan-1-ol
$\Delta H_c^\ominus$ / kJ mol^{-1}	–715	–1371	–2010	–2673
M_r	32.0	46.0	60.0	74.0

(a) (i) Calculate the relative molecular mass of pentan-1-ol and thus estimate $\Delta H_c^\ominus$ for pentan-1-ol using the graph below. *[2]*

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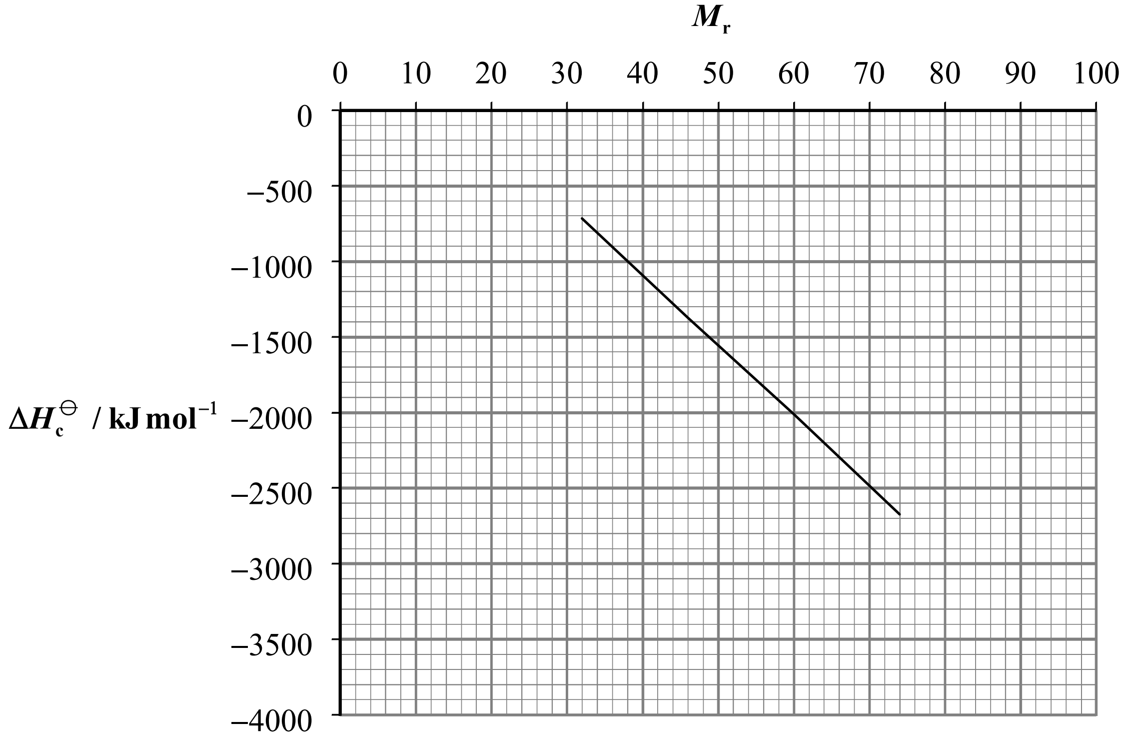

(This question continues on the following page)

(Question 1 (a) continued)

(ii) How would the value of the standard enthalpy of combustion of pentan-2-ol compare with that of pentan-1-ol? Explain your reasoning. *[2]*

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(b) The reaction between methanol and oxygen is spontaneous at all temperatures. Explain why methanol vapour is stable in air, but the mixture reacts quickly when ignited. *[2]*

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(c) (i) 10.0 g of solid NaOH is added to 100 g of water at 23.2 °C in a glass beaker. The solution is stirred and a maximum temperature of 44.6 °C is reached. Calculate the heat produced by the reaction. (Assume the specific heat capacity of the solution is 4.20 $\text{J g}^{-1}\ {}^{\circ}\text{C}^{-1}$.) *[3]*

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(ii) Calculate the enthalpy change for dissolving solid NaOH in water in kJ mol^{-1}. *[1]*

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(iii) The value given in the literature under similar conditions is $-42.7\ \text{kJ mol}^{-1}$. Suggest a reason why the calculated value of the enthalpy change of solution is different from the literature value and propose an improvement in the procedure to obtain a more accurate value. *[2]*

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2. Indigo is a blue dye which contains only carbon, nitrogen, hydrogen and oxygen.

(a) 2.036 g of indigo was completely oxidised to produce 5.470 g of carbon dioxide and 0.697 g of water. Calculate:

(i) the percentage by mass of carbon in indigo; *[2]*

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(ii) the percentage by mass of hydrogen in indigo. *[2]*

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(b) If the percentage by mass of nitrogen in the indigo sample is 10.75 %, determine the empirical formula of indigo. *[3]*

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(c) If the molar mass is approximately 260 $g\,mol^{-1}$, determine the molecular formula of indigo. *[2]*

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3. This question deals with gases and liquids.

(a) The mass of a gas sample is measured under certain conditions. List the variables that must be measured and show how these can be used to determine the molar mass of the gas. *[4]*

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(b) As a volatile liquid in an isolated container evaporates, its temperature drops. Account for this observation in terms of the behaviour of the molecules. *[2]*

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(c) A small amount of a volatile liquid is added to a $50.0\ cm^3$ evacuated container. Twice the amount of the same liquid is added to a second $50.0\ cm^3$ evacuated container, and separately to a $100\ cm^3$ evacuated container. The three systems are allowed to reach equilibrium at the same temperature, and some liquid remains in each flask. Compare the pressure due to the vapour in the three containers and explain your answer. *[3]*

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4. A blue aqueous solution of copper(II) sulfate, $CuSO_4$, is electrolysed using copper electrodes.

(a) Write balanced half-equations, with state symbols, for the reactions occurring at the:

anode (positive electrode): . . . . *[1]*

cathode (negative electrode): . . . . *[1]*

(b) State whether or not the colour of the solution will change as the electrolysis proceeds. Explain your answer. *[1]*

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(c) Write a balanced chemical equation for the products formed if the copper anode is replaced by a graphite anode. *[2]*

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(d) State whether or not the colour intensity and pH of the solution will change as the electrolysis proceeds in (c) above. *[2]*

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(e) Calculate the mass of copper produced when a current of 0.180 amperes is passed through a 1.0 $mol\,dm^{-3}$ copper sulfate solution for 20 minutes 10 seconds. *[3]*

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SECTION B

*Answer **two** questions. Write your answers in a continuation answer booklet. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.*

5. (a) The isotopes of sulfur occur naturally in the following percentages:

$$^{32}S: 95.0\ \%,\ ^{33}S: 0.76\ \%,\ ^{34}S: 4.20\ \%, \text{ and } ^{36}S: 0.020\ \%$$

(i) Calculate the relative atomic mass of sulfur to three significant figures. *[2]*

(ii) Determine the number of neutrons in the atom of the **least** abundant sulfur isotope. *[1]*

(b) (i) Describe how the first **four** ionisation energies of aluminium vary. (You may wish to sketch a graph to illustrate your answer.) *[2]*

(ii) State the electronic configurations of aluminium, boron and magnesium. Explain how the first ionisation energy of aluminium compares with the first ionisation energies of boron and magnesium. *[5]*

(c) When hydrogen gas is placed in an electric discharge tube, an emission spectrum is obtained. Sketch the spectrum, labelling its high energy end. Explain why such a spectrum is obtained. *[3]*

(d) (i) Explain why lithium, sodium, and potassium are placed in the same group of the periodic table. Your answer should refer to their melting points, ionisation energies and electronic arrangements. *[4]*

(ii) State and explain the trend in the chemical reactivity down group 1. Describe, with the aid of balanced equations, the chemical reactions of sodium metal with water and with chlorine gas. *[8]*

6. (a) (i) Draw Lewis structures to represent BF_3, NF_3 and BF_4^-. *[3]*

(ii) Use the principles of the Valence Shell Electron Pair Repulsion (VSEPR) theory to predict the shapes of the above three species. Compare and account for the bond angles in NF_3 and BF_4^- in terms of VSEPR theory. *[5]*

(iii) Explain the meaning of the term *hybridisation*. State the type of hybridisation shown by the central atoms in BF_3 and NF_3. *[3]*

(iv) Explain the term *polar bond*. Predict and explain the polarity of the **bonds** within BF_3 and NF_3. State whether BF_3 and NF_3 are polar molecules. Explain your answer. *[5]*

(b) (i) Explain what is meant by a *sigma* (σ) and a *pi* (π) bond. Describe a double bond and a triple bond in terms of σ and π bonds. *[4]*

(ii) Define the term *delocalisation*. *[1]*

(iii) Alkenes undergo addition reactions. Thermodynamic data for three addition reactions are given below:

$$CH_2{=}CH{-}CH_2{-}CH_2{-}CH_3 + H_2 \rightarrow CH_3{-}CH_2{-}CH_2{-}CH_2{-}CH_3 \qquad \Delta H_1 = -126\ \text{kJ mol}^{-1}$$

$$CH_2{=}CH{-}CH_2{-}CH{=}CH_2 + 2H_2 \rightarrow CH_3{-}CH_2{-}CH_2{-}CH_2{-}CH_3 \qquad \Delta H_2 = -254\ \text{kJ mol}^{-1}$$

$$CH_2{=}CH{-}CH{=}CH{-}CH_3 + 2H_2 \rightarrow CH_3{-}CH_2{-}CH_2{-}CH_2{-}CH_3 \qquad \Delta H_3 = -226\ \text{kJ mol}^{-1}$$

Show the data on an enthalpy diagram and account for the differences in terms of the bonds in each molecule. *[4]*

7. (a) (i) Draw the structural formula of methyl methanoate. State the conditions and the starting materials for the preparation of methyl methanoate in the laboratory. Write a balanced chemical equation for the reaction. *[6]*

(ii) Draw the structural formula of an isomer of methyl methanoate. State **two** physical properties and **one** chemical property that would be different for the two compounds. State how **each** of these properties differ for the two compounds. *[5]*

(b) (i) Explain the term *condensation* and state the structural features of the monomers required to form condensation polymers. How does addition polymerisation differ from condensation polymerisation? *[3]*

(ii) Terylene is a polymer produced from the polymerisation of the two monomers ethane-1,2-diol and benzene-1,4-dicarboxylic acid. State what type of polymer Terylene is and draw the structural formula of its repeating unit. *[3]*

(c) (i) Draw the structures of 2-chloropropanoic acid and 2-hydroxypropanoic acid. *[2]*

(ii) 2-chloropropanoic acid can be converted to 2-hydroxypropanoic acid by nucleophilic substitution. Define the term *nucleophile* and state the nucleophile required for this reaction. *[2]*

(iii) 2-chloropropanoic acid and 2-hydroxypropanoic acid can both show optical activity. Identify the feature which both molecules possess that accounts for this property. When 2-hydroxypropanoic acid is formed from 2-chloropropanoic acid, the product shows **no** optical activity. Deduce the type of nucleophilic substitution that takes place and explain your answer. *[4]*

8. When steam is passed over heated carbon, the following equilibrium is established:

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g)$$

The value of the equilibrium constant (K_c) at various temperatures is given in the table below:

Temperature / K	700	1000	1300
Equilibrium constant (K_c)	4.88×10^{-5}	4.51×10^{-2}	1.88

(a) Write the expression for the equilibrium constant and give its units. Deduce whether the forward reaction is endothermic or exothermic and state how you reached this conclusion. *[4]*

(b) Predict and explain the effect of an increase in temperature, total pressure and surface area of carbon on the:

(i) rate of the forward reaction; *[6]*

(ii) $[H_2O]:[H_2]$ ratio; *[6]*

(iii) value of the equilibrium constant. *[3]*

(c) In the above experiment, the surface of the carbon is sprayed with a catalyst. Draw an appropriate energy level diagram for the reaction, showing the effect of the catalyst. State the way in which the catalyst affects the rate of the forward reaction, the rate of the reverse reaction and the overall position of equilibrium. *[6]*