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

N02/420/H(2)+

CHEMISTRY
HIGHER LEVEL
PAPER 2

Monday 18 November 2002 (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 following enthalpy changes (in kJ mol^{-1}) refer to sodium chloride and its constituent elements.

$\Delta H^{\ominus}_{formation}$	sodium chloride	–411
$\Delta H^{\ominus}_{atomisation}$	sodium	+109
$\Delta H^{\ominus}_{atomisation}$	chlorine	+121
1st ionisation energy	sodium	+494
1st electron affinity	chlorine	–364

(a) (i) State the meaning of the + and – signs in the enthalpy values. *[1]*

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(ii) Explain the meaning of the symbol $\ominus$. *[1]*

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(b) Write an equation, including state symbols, for each of the above enthalpy changes. *[5]*

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(This question continues on the following page)

(Question 1 continued)

(c) The given values can be used to calculate the lattice enthalpy of sodium chloride.

(i) Define the term *lattice enthalpy*. *[1]*

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(ii) Construct a Born-Haber cycle and hence calculate the lattice enthalpy of sodium chloride. *[4]*

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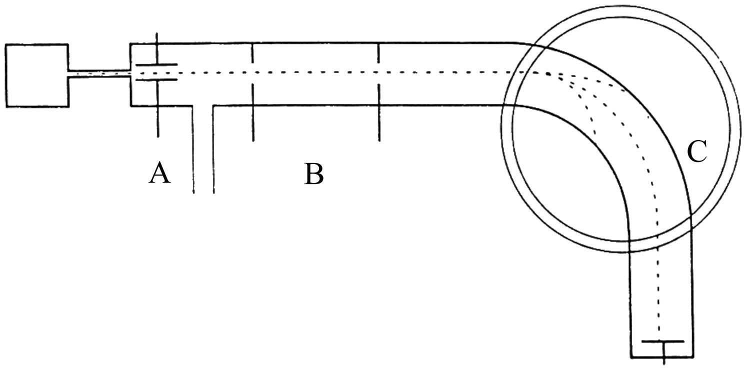
2. The following is a diagram of a mass spectrometer.



(a) Identify the parts labelled A, B, and C. *[3]*

A: . . . .

B: . . . .

C: . . . .

(b) State and explain which **one** of the following ions will undergo the greatest deflection, under the same conditions, in a mass spectrometer. *[2]*

$^{6}Li^{+}$ $^{6}Li^{2+}$ $^{7}Li^{+}$ $^{7}Li^{2+}$

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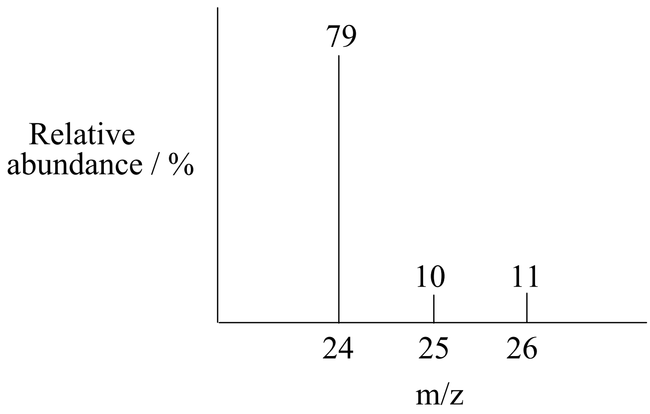
(Question 2 continued)

(c) The mass spectrum for an element is given below.



(i) Explain why there is more than one peak. *[1]*

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(ii) Calculate, to two decimal places, the relative atomic mass of the element. *[2]*

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3. A balloon, which can hold a maximum of $1100\ \text{cm}^3$ of air before bursting, contains $955\ \text{cm}^3$ of air at 5 °C.

(a) Determine whether the balloon will burst if the temperature is increased to 25 °C. Assume that the pressure of the gas in the balloon remains constant. *[3]*

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(b) Use the kinetic theory to explain what happens to the air particles inside the balloon as the temperature is increased to 25 °C. *[2]*

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4. A half-cell (A) is set up by placing a platinum electrode in a solution containing both Fe^{2+} and Fe^{3+} ions at a concentration of $1\ mol\ dm^{-3}$. This half-cell is then connected by means of a salt bridge to another half-cell (B) containing an iron electrode in a $1\ mol\ dm^{-3}$ solution of Fe^{2+} ions.

(a) State the function of the salt bridge. *[1]*

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(b) The two electrodes are connected externally.

(i) Use Table 15 of the Data Booklet to determine the cell standard electrode potential. *[2]*

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(ii) Give the redox reactions that occur in each half-cell. *[2]*

A: . . . .

B: . . . .

(iii) State the direction of the electron flow in the external circuit. *[1]*

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5. An element X reacts with oxygen to form the oxide X_2O_3.

(a) Write a balanced equation for the reaction. *[1]*

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(b) If 2.199 g of the oxide was obtained from 1.239 g of X, calculate the relative atomic mass of X and identify the element. *[5]*

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(c) Nitrogen also forms an oxide on reaction with oxygen. This oxide contains 25.9 % of nitrogen and 74.1 % of oxygen by mass. Calculate the empirical formula of this second oxide. *[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.*

6. (a) Draw Lewis structures of the following species.

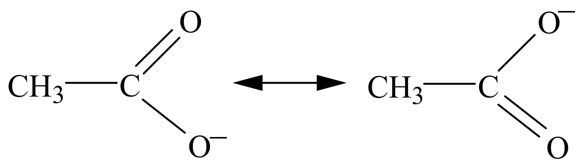
BF_4^- H_2CO NO_2^+ NO_2^- *[4]*

(b) Predict the shape and bond angle of each of the species in (a), explaining your choice using VSEPR theory. *[8]*

(c) Explain the term *hybridisation* and state the type of hybridisation in each of the species in (a). *[3]*

(d) Ethanoic acid contains two different types of carbon to oxygen bond. Explain how the carbon and oxygen atoms combine to form each of those bonds and compare their bond lengths and strengths. *[7]*

(e) The structure of the ethanoate ion can be written as shown below.



The stability of the ethanoate ion suggests a different type of carbon to oxygen bond.

(i) Describe the actual carbon to oxygen bond in the ethanoate ion. *[2]*

(ii) Predict a value for the bond length of the carbon to oxygen bond in the ethanoate ion. *[1]*

7. When 1 mole of hydrogen iodide is allowed to dissociate into its elements at 440 °C in a 1.0 dm^3 vessel, only 0.78 moles of hydrogen iodide are present at equilibrium.

(a) Write an equation for the equilibrium reaction, including state symbols. *[2]*

(b) (i) Write the expression for the equilibrium constant K_c for the above reaction and state its units. *[2]*

(ii) Calculate the equilibrium constant for the reaction at 440 °C using the information given above. *[4]*

(c) If $K_c = 0.04$ in the gas phase at 600 °C, deduce whether the dissociation of hydrogen iodide is exothermic or endothermic and explain your answer. *[3]*

(d) Predict and explain the effect on the position of equilibrium of

(i) increasing the total pressure
(ii) adding more hydrogen iodide at constant pressure
(iii) adding a catalyst. *[6]*

(e) The equilibrium constants for the dissociation of hydrogen chloride and hydrogen bromide are given below.

$$K_c(\text{HCl}) = 1.0 \times 10^{-17}$$
$$K_c(\text{HBr}) = 1.0 \times 10^{-9}$$

Explain what information these values give about the extent of each dissociation compared to that of hydrogen iodide. *[1]*

(f) Ammonia is manufactured by the Haber Process, for which the reaction is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ}$$

A *heterogeneous* catalyst of iron is used.

(i) Sketch an enthalpy level diagram showing the enthalpy change and the activation energy of the reaction. *[3]*

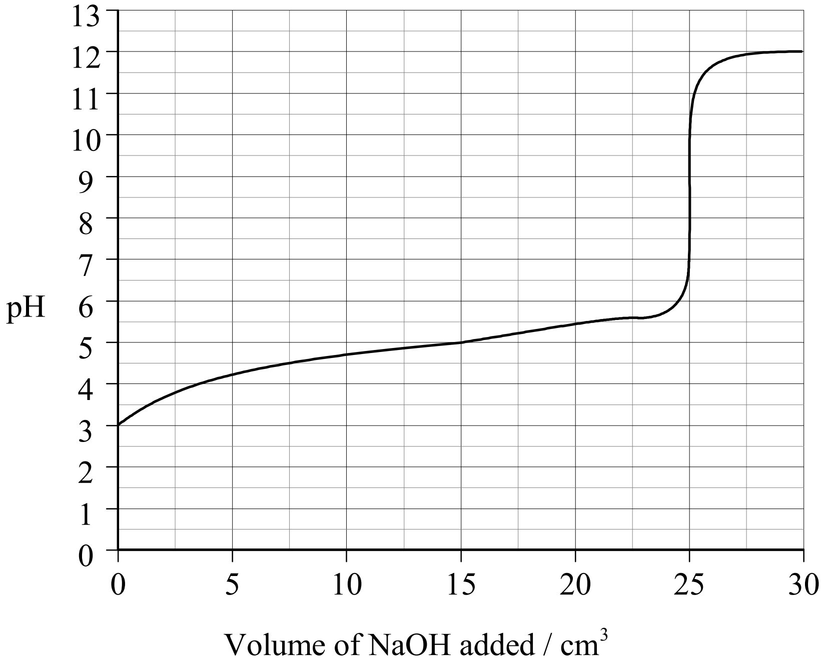
(ii) State and explain the effect of the catalyst on the activation energy of the reaction. *[2]*

(iii) Explain the term *heterogeneous* and outline how such catalysts work. *[2]*

8. Benzoic acid is a weak *monoprotic* acid.

(a) Explain the term *monoprotic* acid. *[1]*

(b) The experimentally determined graph below shows the change in pH when 0.10 mol dm^{-3} aqueous sodium hydroxide is added to 25 cm^3 of 0.10 mol dm^{-3} aqueous benzoic acid.



(i) Calculate the pH when the benzoic acid is half-neutralised and explain how you arrived at your answer. *[2]*

(ii) Explain by reference to Table 17 of the Data Booklet why phenolphthalein is a suitable indicator for this titration. *[2]*

(c) The experiment was repeated using 25 cm^3 of 0.10 mol dm^{-3} hydrochloric acid instead of benzoic acid.

(i) Sketch the graph you would expect from the results of this second experiment. *[3]*

(ii) State and explain any similarities and differences between the two graphs. *[4]*

(d) Explain how an indicator works using

$$HIn \rightleftharpoons H^+ + In^-$$

where HIn represents the formula of the indicator. *[2]*

(This question continues on the following page)

(Question 8 continued)

(e) A mixture of benzoic acid and sodium benzoate can act as a *buffer solution*.

(i) Define the term *buffer solution* and describe what happens when acid is added to a buffer solution. *[5]*

(ii) Calculate the pH of a solution containing 7.2 g of sodium benzoate in $1.0\ \text{dm}^3$ of $2.0 \times 10^{-2}\ \text{mol dm}^{-3}$ benzoic acid, $(K_a = 6.3 \times 10^{-5}\ \text{mol dm}^{-3})$ stating any assumptions that you have made. *[6]*

9. (a) Alkanes are often described as having low reactivity, although they do react with halogens.

(i) Explain why alkanes are unreactive. *[2]*

(ii) The first step in the reaction of propane with bromine can be represented by the equation.

$$Br_2 \rightarrow 2Br\bullet$$

State the type of species formed in this step and name the type of bond fission. *[2]*

(iii) Propane could be converted to 1-bromopropane or 2-bromopropane in this reaction. Deduce the peak height ratios in the ^{1}H NMR spectra of each of these three compounds. *[3]*

(b) The reaction between 1-bromopropane and warm dilute sodium hydroxide solution is described as an S_N2 nucleophilic substitution reaction.

(i) Explain each of the terms in S_N2. *[3]*

(ii) Write an equation and a mechanism for the reaction. *[5]*

(c) (i) 1-bromopropane is described as a *primary* halogenoalkane and 2-bromopropane is described as a *secondary* halogenoalkane. Explain these terms with reference to the two examples given. *[2]*

(ii) Give the structural formula of a tertiary halogenoalkane. *[1]*

(iii) State the type of substitution reaction undergone by tertiary halogenoalkanes. *[1]*

(d) Propan-1-ol, in the presence of a small amount of oxidising agent, forms compound X, and when refluxed with an excess of oxidising agent, forms compound Y.

(i) Identify a suitable oxidising agent and state the colour change. *[2]*

(ii) Draw the structural formulas of both compound X and compound Y. *[2]*

(iii) Explain why alkanoic acids are more acidic than alkanols. *[2]*