INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

CHEMISTRY
HIGHER LEVEL
PAPER 2

Tuesday 16 May 2000 (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. You may use the lined pages at the end of this paper or continue 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

*Answer **all** questions from this section.*

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. (a) Automobile engines produce a variety of air pollutants at high temperatures. One of these pollutants is nitrogen(II) oxide, NO, formed in the following reaction:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H^{\ominus} \text{ is positive}$$

(i) What is the significance of the positive value for $\Delta H^{\ominus}$? *[1]*

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(ii) State and explain the effect of a decrease in temperature on the value of K_c for this reaction. *[2]*

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(iii) In an experiment, the initial concentrations are $N_2(g) = 1.6$ mol dm^{-3} and $O_2(g) = 1.6$ mol dm^{-3}. Calculate the concentration of the NO(g) after equilibrium is established. ($K_c = 1.7 \times 10^{-3}$) *[3]*

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(This question continues on the following page)

(Question 1 continued)

(b) The depletion of ozone, O_3, in the upper atmosphere can be caused by the reaction of automobile exhaust gases, such as NO, with the ozone. The reaction between $O_3(g)$ and NO(g) has been studied and the following data were obtained at 25 °C.

Experiment	[NO(g)] / mol dm^{-3}	[O_3(g)] / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	1.00×10^{-6}	3.00×10^{-6}	0.660×10^{-4}
2	1.00×10^{-6}	6.00×10^{-6}	1.32×10^{-4}
3	3.00×10^{-6}	9.00×10^{-6}	5.94×10^{-4}
4	4.50×10^{-6}	7.20×10^{-6}	

(i) Give the rate equation for the reaction between NO(g) and O_3(g), showing your reasoning. *[3]*

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(ii) Calculate the value of the rate constant, *k*, stating its units. *[2]*

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(iii) Calculate the rate of the reaction for Experiment 4. *[1]*

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2. Select the substance with the higher boiling point in each of the following pairs. Explain your reasoning.

(a) C_2H_6 and C_3H_8 *[3]*

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(b) CH_3CH_2OH and CH_3OCH_3 *[3]*

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3. (a) In the reaction

$$2H_2O(l) \rightarrow H_3O^+(aq) + OH^-(aq)$$

use the Brønsted-Lowry Theory to discuss the acidic and/or basic nature of water. *[2]*

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(b) What is the conjugate **base** of the hydroxide ion, OH^-? *[1]*

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(c) State **one** method which could be used to decide whether a solution of 0.10 $mol\,dm^{-3}$ acid is strong or weak. Give the results expected in each case. *[3]*

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(d) In a titration experiment, 40.0 cm^3 of 0.150 $mol\,dm^{-3}$ NaOH was added to 60.0 cm^3 of 0.200 $mol\,dm^{-3}$ $CH_3(CH_2)_3COOH$ ($K_a = 1.38 \times 10^{-5}$ $mol\,dm^{-3}$). Calculate the pH of this mixture. *[4]*

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4. (a) Define a reducing agent in terms of electrons. *[1]*

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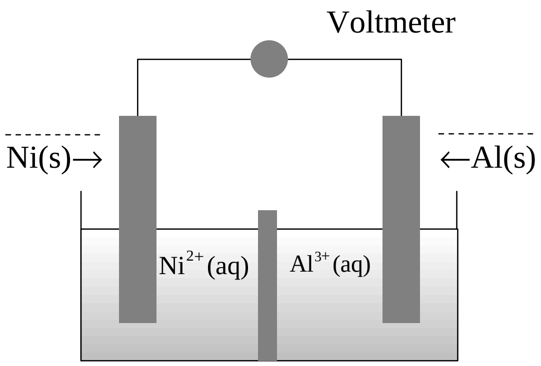
(b) In the following representation of a cell, label each electrode with a + or a – sign, as appropriate, and draw an arrow on the connecting wire to indicate the direction of electron flow. (Refer to Table 15 of the Chemistry Data Booklet.) *[2]*



(c) (i) Write the balanced equation for the spontaneous reaction in the above cell. *[2]*

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(ii) Calculate the standard cell potential. *[2]*

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(d) Chromium is deposited from an acidic solution containing the dichromate(VI) ion, according to the equation

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 12e^- \rightarrow 2Cr(s) + 7H_2O(l)$$

How many moles of Cr(s) can be deposited by a current of 8.00 A flowing for 2.00 hours? *[5]*

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SECTION B

*Answer **two** questions. You may use the lined pages at the end of this paper or continue 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. This question is concerned with compounds having the molecular formula C_3H_8O. (Refer to the Chemistry Data Booklet to help answer this question.)

(a) Draw the full structural formulas of the **three** possible isomers and give the name of each. *[6]*

(b) Predict how each of these isomers would behave when reacted with limited (*i.e.* **not** in excess) acidified potassium dichromate(VI) solution and describe any **observation** that could be made. Write the structures of any organic products formed and give their names. *[8]*

(c) The infra-red spectrum of one of the three possible isomers shows an absorption band at 1000–1300 cm^{-1}, but no absorption bands above 3000 cm^{-1}. State to which of these three isomers this spectrum can be assigned and give your reasoning. *[3]*

(d) Two of these isomers give the following NMR spectra:

- Spectrum A with peak areas in the ratio 3:2:2:1
- Spectrum B with peak areas in the ratio 6:1:1

Assign each of these spectra to **one** of the isomers you have drawn and outline your reasoning. *[4]*

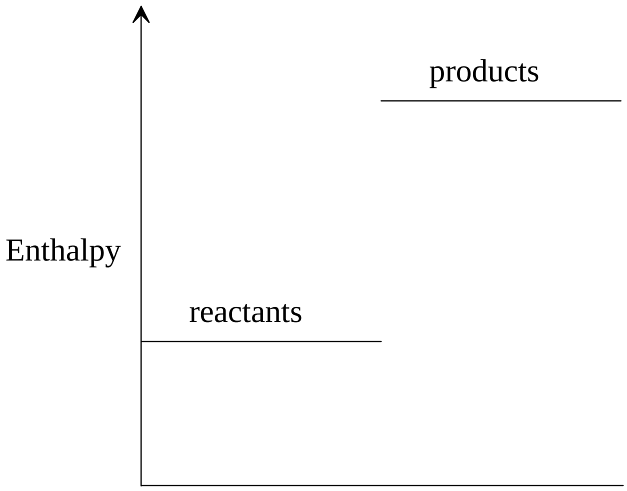
(e) Two of these isomers can be dehydrated to give the same product. Identify the two isomers and give the structure of the product. Give an equation for a characteristic reaction of the product. *[4]*

6. (a) (i) The oxides of magnesium and silicon have high melting points whereas the oxides of phosphorus (P_4O_6) and sulphur (SO_2) have low melting points. Explain the difference in melting points by referring to bonding and structure in each case. *[8]*

(ii) Each of the four oxides is mixed with a separate sample of pure water. For each of the oxides, state whether it is soluble or insoluble in water. For each of the oxides, state whether the **resulting liquid** is acidic, alkaline or neutral. Write an equation for each reaction. *[10]*

(b) Give the electronic configuration of the d-block element titanium. State **three** characteristics of d-block elements and account for each in terms of electrons. *[7]*

7. The enthalpy diagram for a reaction between two aqueous solutions at room temperature is shown below.



(a) (i) Give the sign of ΔH for this reaction and indicate whether it is endothermic or exothermic. State the relative strengths of the bonds in the products and reactants. *[3]*

(ii) This reaction is spontaneous at room temperature. Use this information along with that in (i) to give the signs of $\Delta G^{\ominus}$ and $\Delta S^{\ominus}$, outlining your reasoning in each case. Comment on the meaning of the sign of $\Delta S^{\ominus}$ in terms of the relative disorder of the reactants and products. *[5]*

(iii) Describe an experiment that could be conducted in a school laboratory to determine the value of ΔH (in kJ mol^{-1}) for this reaction. Show the calculations that would need to be carried out to obtain the value of ΔH. *[6]*

(iv) Outline **two** sources of error in the experimental procedure that could result in a calculated ΔH value that is *smaller* than the accepted value and suggest a way that **one** of these could be minimised. *[3]*

(v) Discuss how the spontaneity of this reaction would change as the temperature is increased from room temperature, and also as the temperature is decreased from room temperature. Outline your reasoning in each case. *[4]*

(b) Assume the reaction in (a) can be represented as

$$2A_2 + B_2 \rightarrow 2A_2B$$

(i) Derive an expression that could be used to find $\Delta H_{\text{reaction}}$ from the bond energies involved. *[2]*

(ii) Discuss the fact that $\Delta H_{\text{reaction}}$ values found from bond energies often differ from those calculated using ΔH_f values. Describe the conditions under which the best agreement is achieved between these two methods. *[2]*

8. (a) Nitrogen forms a number of different compounds with hydrogen including

NH_3 H_2NNH_2 HNNH

(i) Write Lewis electron dot structures for N_2, NH_3, H_2NNH_2 and HNNH. *[4]*

(ii) Compare the bond angles between the hydrogen atoms in H_2NNH_2 and HNNH. Explain your reasoning. *[3]*

(iii) Give the hybridisation of the nitrogen in N_2, NH_3 and HNNH. *[3]*

(iv) One of the compounds exists in two isomeric forms. Identify the compound, draw the two isomers and compare their polarities. *[4]*

(b) Methanoic acid, HCOOH, is a weak acid. When it loses a proton the methanoate ion, $HCOO^-$, is formed.

(i) State the number of sigma bonds and the number of pi bonds in HCOOH and describe the difference between such bonds. *[4]*

(ii) Compare the carbon–oxygen bond lengths in HCOOH, giving your reasoning. *[2]*

(iii) Compare the carbon–oxygen bond lengths in $HCOO^-$, giving your reasoning. *[2]*

(iv) Write two Lewis electron dot structures for the $HCOO^-$ ion and state how the bonding in the ion is related to these structures. *[3]*
