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

88046102

CHEMISTRY
HIGHER LEVEL
PAPER 2

Wednesday 17 November 2004 (afternoon)

2 hours 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your school code and candidate code 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 school code and candidate code 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 questions in the spaces provided.

1. 27.82 g of hydrated sodium carbonate crystals, $Na_2CO_3 . xH_2O$, was dissolved in water and made up to 1.000 dm^3. 25.00 cm^3 of this solution was neutralized by 48.80 cm^3 of hydrochloric acid of concentration 0.1000 mol dm^{-3}.

    (a) Write an equation for the reaction between sodium carbonate and hydrochloric acid. *[2]*

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    (b) Calculate the molar concentration of the sodium carbonate solution neutralized by the hydrochloric acid. *[3]*

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    (c) Determine the mass of sodium carbonate neutralized by the hydrochloric acid and hence the mass of sodium carbonate present in the 1.000 dm^3 of solution. *[3]*

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(Question 1 continued)

    (d)   Calculate the mass of water in the hydrated crystals and hence find the value of x.   *[4]*

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Turn over

2. The alkanes are a *homologous series* of *saturated hydrocarbons*.

(a) State the meaning of each of the following terms.

(i) *homologous series* [2]

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(ii) *hydrocarbon* [1]

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(iii) *saturated* [1]

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(b) (i) State and explain the trend in the boiling points of the first five alkanes. [2]

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(ii) Explain why the enthalpies of combustion of alkanes are negative values. [1]

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(c) State the products of the complete combustion of alkanes. [1]

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3. The equation for the decomposition of calcium carbonate is given below.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$
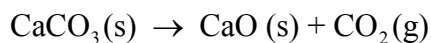
At 500 K, ΔH for this reaction is $+177$ kJ mol^{-1} and ΔS is $+161$ J K^{-1} mol^{-1}.

(a) Explain why ΔH for the reaction above cannot be described as $\Delta H_f^{\ominus}$. *[2]*

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(b) State the meaning of the term ΔS. *[1]*

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(c) Calculate the value of ΔG at 500 K and determine, giving a reason, whether or not the reaction will be spontaneous. *[3]*

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4. The indicator bromophenol blue, $HIn\,(aq)$, has a form that is yellow and an $In^-\,(aq)$ form that is blue.

(a) Write an equation to show how bromophenol blue acts as an indicator. *[1]*

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(b) State and explain the colour of bromophenol blue *[3]*

(i) on the addition of a strong acid.

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(ii) at the equivalence point of a titration.

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5. Elements with atomic number 21 to 30 are d-block elements.

(a) Identify which of these elements are **not** considered to be typical transition elements.   *[1]*

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(b) Complex ions consist of a central metal ion surrounded by ligands. Define the term *ligand*.   *[2]*

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(c) Complete the table below to show the oxidation state of the **transition element**.   *[3]*

ion	$Cr_2O_7^{2-}$	$[CuCl_4]^{2-}$	$[Fe(H_2O)_6]^{3+}$
oxidation state			

(d) Identify **two** transition elements used as catalysts in industrial processes, stating the process in each case.   *[2]*

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(e) Apart from the formation of complex ions and apart from their use as catalysts, state **two** other properties of transition elements.   *[2]*

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SECTION B

*Answer **two** questions. Write your answers on the answer sheets provided. Write your school code and candidate code on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

6. *X* is an organic compound composed of carbon, hydrogen and oxygen, containing 48.63 % carbon and 8.18 % hydrogen by mass.

(a)   Calculate the empirical formula of *X*.   [4]

(b)   The mass spectrum for *X* is shown below.
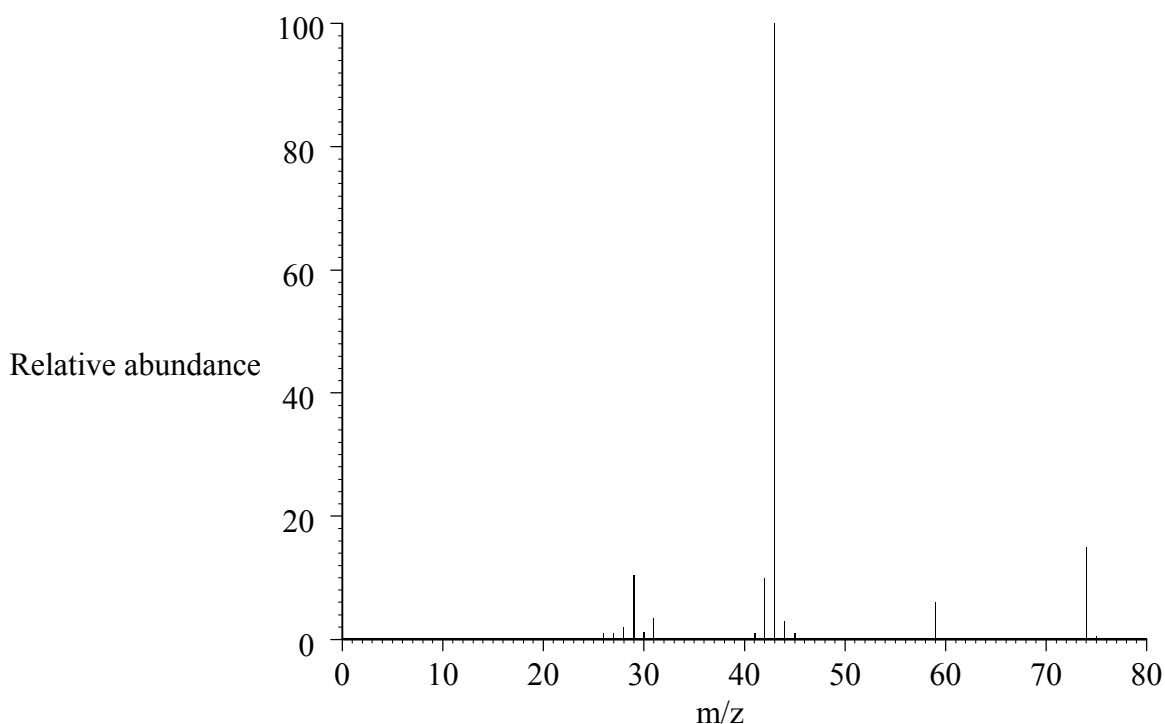
[Source: NIST Mass Spec Data Center, S E Stein, director, "IR and Mass Spectra" in NIST Chemistry WebBook, NIST Standard Reference Database Number 69, Eds. P J Linstrom and W G Mallard, July 2001, National Institute of Standards and Technology, Gaithersburg MD, 20899 (http://webbook.nist.gov)]

(i)   Deduce, giving a reason, the molecular formula of *X*.   [2]

(ii)   Identify the formulas of the fragment ions with m/z values of 45 and 29.   [2]

(This question continues on the following page)

(Question 6 continued)

(c)   The infrared spectrum of X is shown below.
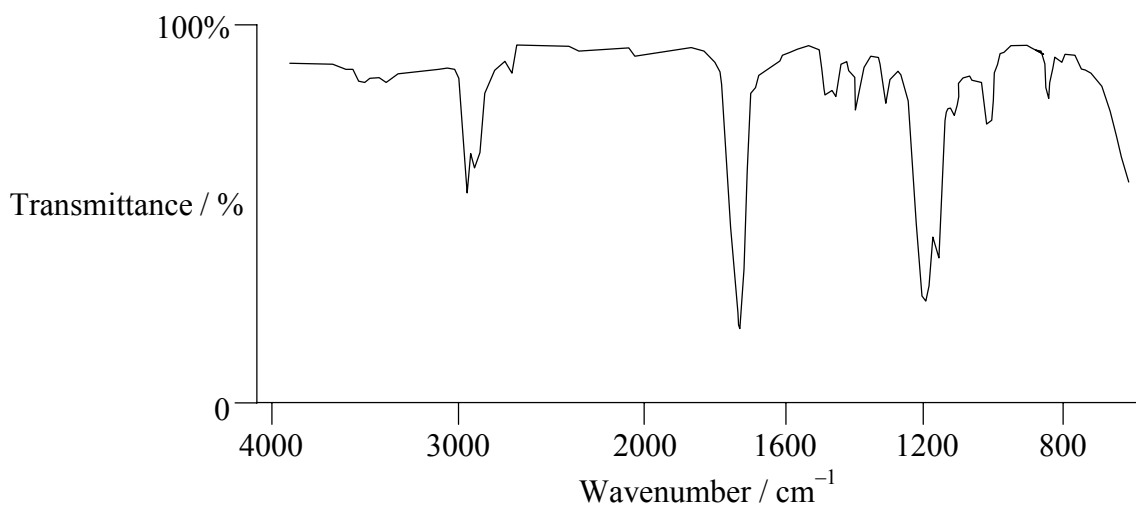
[Source: NIST Standard Reference Data Program
Collect (C) 2003 copyright by the U.S. Secretary of Commerce
on behalf of the United States of America. All rights reserved]

Using the above spectrum,

(i)   explain why *X* is **not** a carboxylic acid.   *[1]*

(ii)   identify, giving reasons, **three** bonds that are present in *X*.   *[3]*

(d)   Deduce the most likely structural formula of *X* based on your answers to (b) and (c). State
       the name of *X* and give **one** use of compounds belonging to this homologous series.   *[3]*

(e)   State and explain the number of peaks compound *X* will show in its low resolution ^{1}H NMR
       spectrum.   *[2]*

(f)   State the names of **two** compounds which could react together to produce *X*. Identify the type
       of reaction and give an equation for the reaction.   *[4]*

(g)   Explain the term *isomerism*.   *[1]*

(h)   Give structural formulas for **two** possible isomers of *X*.   *[2]*

(i)   Predict, giving a reason, whether or not you would expect *X* to be water soluble.   *[1]*

7. (a) In 1954 Linus Pauling was awarded the Chemistry Nobel Prize for his work on the nature of the chemical bond. Covalent bonds are one example of intramolecular bonding.

Explain the formation of the following.

   (i) σ bonding   *[2]*

   (ii) π bonding   *[2]*

   (iii) double bonds   *[1]*

   (iv) triple bonds   *[1]*

(b) Atomic orbitals can mix by hybridization to form new orbitals for bonding.

Identify the type of hybridization present in each of the **three** following molecules. Deduce and explain their shapes.

   (i) OF_2 *[3]*

   (ii) H_2CO *[3]*

   (iii) C_2H_2 *[3]*

(c) Three scientists shared the Chemistry Nobel Prize in 1996 for the discovery of fullerenes. Fullerenes, like diamond and graphite, are allotropes of the element carbon.

   (i) State the structures of and the bonding in diamond and graphite.   *[2]*

   (ii) Compare and explain the hardness and electrical conductivity of diamond and graphite.   *[4]*

   (iii) Predict and explain how the hardness and electrical conductivity of C_{60} fullerene would compare with that of diamond and graphite.   *[4]*

8. Oxygen and nitrogen monoxide react together to form nitrogen dioxide.

$$O_2(g) + 2NO(g) \rightarrow 2NO_2(g)$$
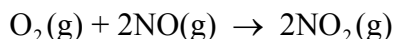
The graph below shows how the initial rate of reaction changed during an experiment in which the initial [NO(g)] was kept constant whilst the initial $[O_2(g)]$ was varied.
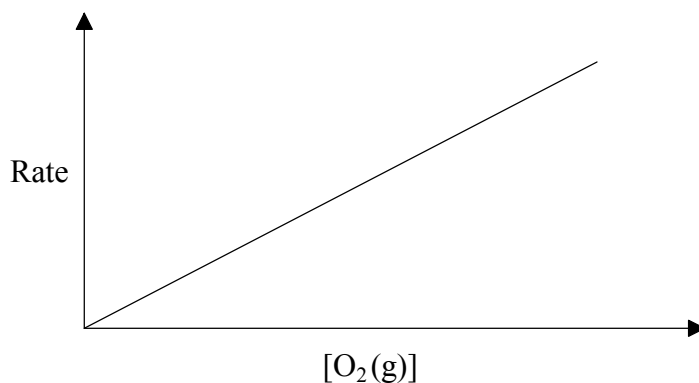
(a) Deduce, giving a reason, the order of reaction with respect to O_2.   *[2]*

(b) In a series of experiments, the initial $[O_2(g)]$ was kept constant while the initial [NO(g)] was varied. The results showed that the reaction was second order with respect to NO. Sketch a graph to show how the rate of reaction would change if the initial [NO(g)] was increased.   *[2]*

(c) Deduce the overall order of this reaction.   *[1]*

(d) State and explain what would happen to the initial rate of reaction if the initial concentration of NO was doubled and that of O_2 was halved.   *[3]*

(e) When the initial values are $[O_2(g)] = 1.0 \times 10^{-2}\,\text{mol dm}^{-3}$ and $[NO(g)] = 3.0 \times 10^{-2}\,\text{mol dm}^{-3}$, the initial rate of reaction is $6.3 \times 10^{-4}\,\text{mol dm}^{-3}\,\text{s}^{-1}$. Write the rate expression for this reaction and calculate the rate constant, stating its units.   *[4]*

(This question continues on the following page)

(Question 8 continued)

(f)   Nitrogen monoxide may also be converted into nitrogen dioxide at high temperature according to the equation below.

$$NO(g) + CO(g) + O_2(g) \rightarrow NO_2(g) + CO_2(g)$$
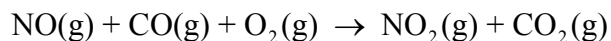
(i)   Sketch a graph of concentration of $NO_2(g)$ produced against **time** for this reaction and annotate the graph to show how the initial rate of reaction could be deduced.   *[3]*

(ii) The results from a series of experiments for this reaction are shown below. Deduce, giving a reason, the order of reaction with respect to each of the reactants.   *[6]*

Experiment	$[NO(g)]$ / mol dm^{-3}	$[CO(g)]$ / mol dm^{-3}	$[O_2(g)]$ / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-1}	4.40×10^{-4}
2	2.00×10^{-3}	1.00×10^{-3}	1.00×10^{-1}	1.76×10^{-3}
3	2.00×10^{-3}	2.00×10^{-3}	1.00×10^{-1}	1.76×10^{-3}
4	4.00×10^{-3}	1.00×10^{-3}	2.00×10^{-1}	7.04×10^{-3}

(g)   Explain why the order of a reaction cannot be obtained directly from the stoichiometric equation.   *[1]*

(h)   (i)   First order reactions have a constant *half-life*. Define the term *half-life* and explain why it is constant for first order reactions.   *[2]*

(ii) The value of k for a first order reaction is $440\,s^{-1}$. Calculate the half-life for this reaction.   *[1]*

9.   The following are standard electrode potentials.

Half-equation	$E^{\ominus}$ / V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	-0.76
$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	-0.44
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	-0.14
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	$+0.34$
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	$+0.77$

(a)   These values were obtained using a standard hydrogen electrode. Describe the materials and conditions used in the standard hydrogen electrode. (A suitably labelled diagram is acceptable.)   *[5]*

(b)   Define the term *oxidizing agent* in terms of electron transfer and identify the strongest oxidizing agent in the list above.   *[2]*

(c)   A cell was set up using zinc in zinc sulfate solution and copper in copper(II) sulfate solution, both solutions being under standard conditions.

   (i)   Calculate the cell potential.   *[1]*

   (ii)   Write an equation for the spontaneous cell reaction.   *[2]*

(d)   Both zinc and tin are used to coat iron to prevent it from rusting. Once the surface is scratched, oxygen and water containing dissolved ions come into contact with the iron and the coating metal.

   (i)   State and explain whether zinc or tin would be more effective in preventing iron from rusting under these conditions.   *[2]*

   (ii)   Electroplating may be used to coat one metal with another metal. Identify the **three** factors affecting the amount of metal discharged during electroplating.   *[3]*

   (iii)   Explain why electrolysis of aqueous zinc sulfate is not used for coating with zinc metal.

                    [2]

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(Question 9 continued)

(e)   Another cell was set up as shown below.
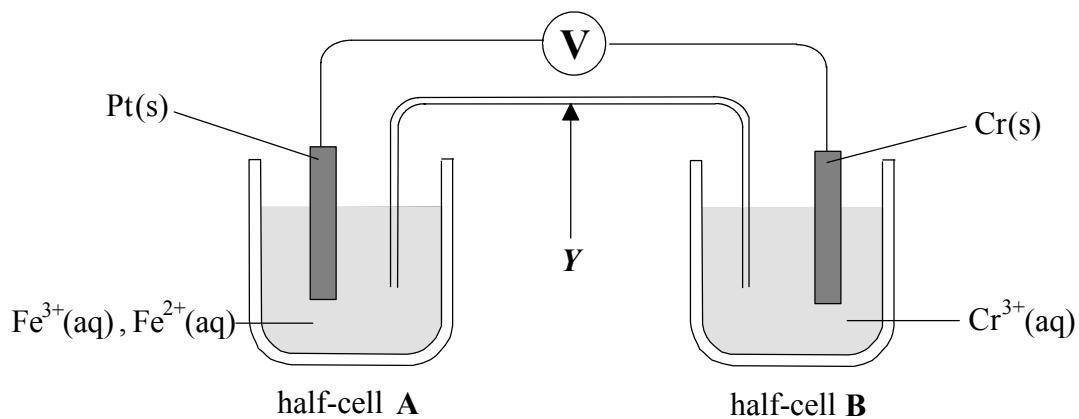
(i)   Identify the part of the cell labelled *Y* and outline its function.   *[2]*

(ii)   Write an equation for the initial reactions at each electrode and hence write an equation for the cell reaction.   *[4]*

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

(iv)   Calculate the cell potential.   *[1]*