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

M03/420/H(2)

CHEMISTRY
HIGHER LEVEL
PAPER 2

Candidate number

Wednesday 14 May 2003 (afternoon)

2 hours 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your candidate number in the box 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 candidate 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 questions in the spaces provided.

1. The following table shows values that appear in the Data Booklet.

Table 1 Covalent (atomic) radii / 10^{-12} m

				N	O	F
				70	66	58
Na	Mg	Al	Si	P	S	Cl
186	160	143	117	110	104	99

Table 2 Ionic radii / 10^{-12} m

				N^{3-}	O^{2-}	F^-
				171	146	133
Na^+	Mg^{2+}	Al^{3+}	Si^{4+}	P^{3-}	S^{2-}	Cl^-
98	65	45	42	212	190	181

(a) Explain why

(i) the magnesium ion is much smaller than the magnesium atom. *[2]*

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(ii) there is a large increase in ionic radius from silicon to phosphorus. *[2]*

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(iii) the ionic radius of Na^+ is less than that of F^-. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(b) Identify which **two** elements from the tables opposite will form the most ionic compound. Explain your answer. *[2]*

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(c) A metal in Table 1 forms an oxide that reacts with both acids and alkalis. Give the formula of the oxide and state the type of oxide. *[2]*

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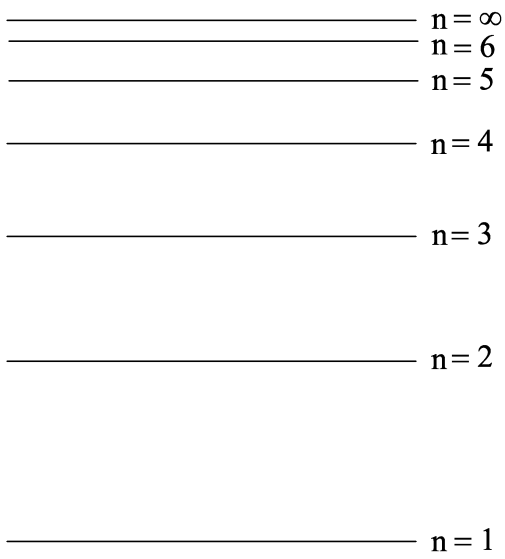
2. (a) The diagram below (not to scale) represents some of the electron energy levels in the hydrogen atom.



(i) Draw an arrow on the diagram to represent the electron transition for the ionization of hydrogen. Label this arrow A. *[2]*

(ii) Draw an arrow on the diagram to represent the lowest energy transition in the visible emission spectrum. Label this arrow B. *[2]*

(b) Tritium, $^{3}_{1}T$, is an isotope of hydrogen.

(i) State the number and type of sub-atomic particles in a tritium atom and the location of each type. *[2]*

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(ii) Write balanced equations to represent the formation of the following compounds, starting with T_2 or T_2O. *[4]*

NT_3: . . . . . .

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NaOT: . . . . . .

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3. (a) An industrial gas mixture is produced by the catalytic reforming of methane using steam.

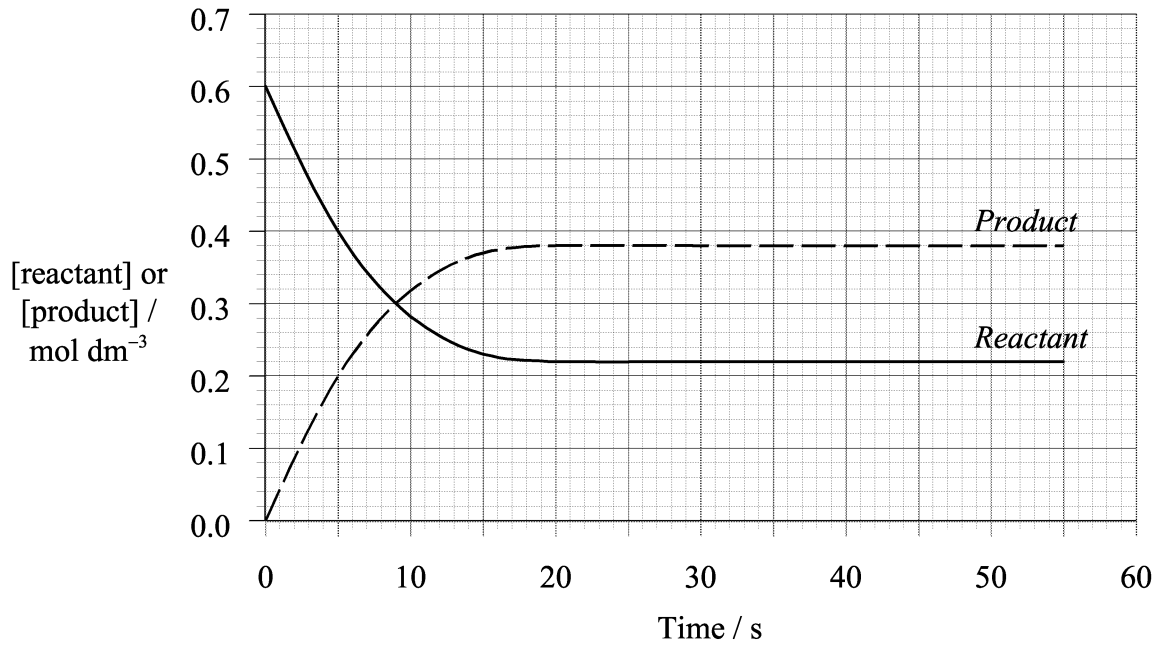
$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ}$$

By circling the appropriate letter(s) below, identify the change(s) that would shift the position of equilibrium to the right.

A	increasing the temperature	B	decreasing the temperature
C	increasing the pressure	D	adding a catalyst
E	decreasing the pressure	F	increasing the concentration of H_2

[2]

(b) The following graph represents the change of concentration of reactant and product during a reaction.



(i) Calculate the average rate of reaction over the first 15 s, stating the units. *[3]*

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(ii) After 19 s the concentrations of the reactant and product do not change. State what this indicates about the reaction. *[1]*

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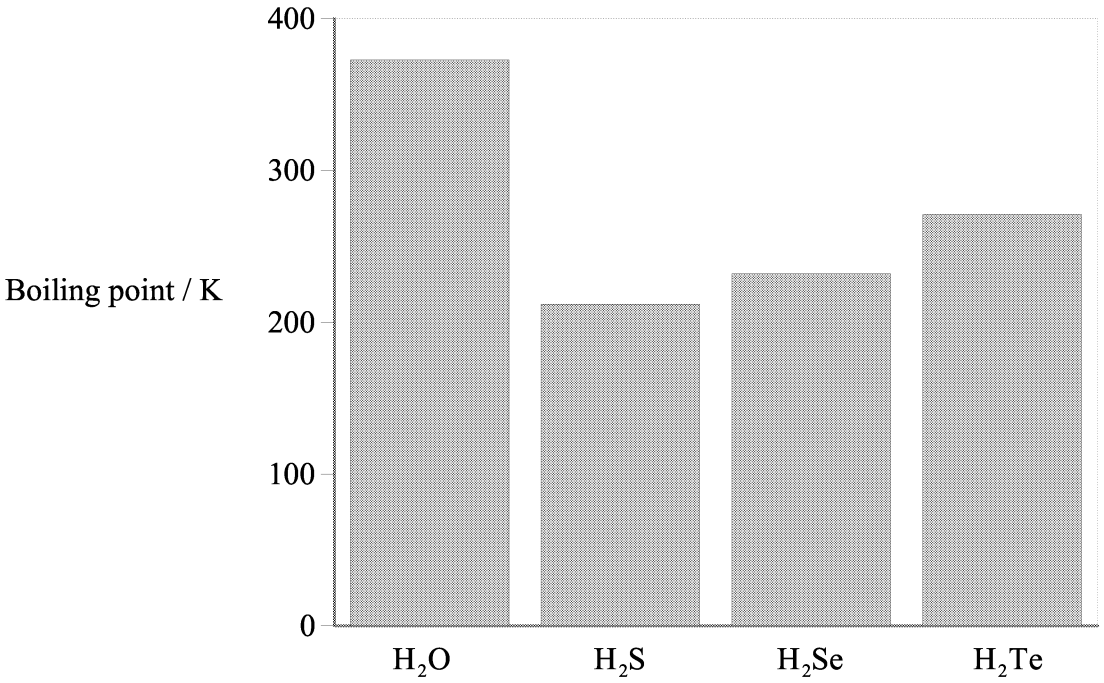
4. The boiling points of the hydrides of the group 6 elements are shown below.



(a) Explain the trend in boiling points from H_2S to H_2Te. *[2]*

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(b) Explain why the boiling point of water is higher than would be expected from the group trend. *[2]*

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5. (a) Halogenoalkanes undergo nucleophilic substitution reactions. The rates and mechanisms of these reactions depend on whether the halogenoalkane is primary, secondary or tertiary. Explain the term *nucleophilic substitution*. *[2]*

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(b) The formula C_4H_9Br represents more than one compound. Using this formula, draw a structure (showing all bonds between carbon atoms) to represent a halogenoalkane that is

(i) primary. *[1]*

(ii) secondary. *[1]*

(iii) tertiary. *[1]*

(This question continues on the following page)

(Question 5 continued)

(c) The stoichiometric equation for a nucleophilic substitution reaction is given below.

$$(CH_3)_3CBr + OH^- \rightarrow (CH_3)_3COH + Br^-$$

The reaction takes place by means of a two-step mechanism.

(i) Write an equation for each step. *[2]*

(ii) Define the following terms. *[2]*

Molecularity

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Rate-determining step

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(iii) Identify the rate-determining step in the mechanism in (i) above. *[1]*

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SECTION B

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

6. (a) (i) Draw a graph to show the distribution of energies in a sample of gas molecules. Label the axes and label your curve T_1. Using the same axes, draw a second curve to represent the distribution of energies at a higher temperature. Label this curve T_2. *[3]*

(ii) State and explain, with reference to your graph, what happens to the rate of a reaction when the temperature is increased. *[2]*

(b) (i) State and explain the effect of a catalyst on the rate of a reaction. *[3]*

(ii) Distinguish between the terms *heterogeneous* and *homogeneous* catalyst. *[2]*

(iii) For **each** type of catalyst, state an example and write an equation for a reaction it catalyses. *[4]*

(c) The data below refer to a reaction between X and Y.

	Initial concentration / mol dm^{-3}		**Initial rate of reaction / mol dm^{-3} s^{-1}**
Experiment	**X**	**Y**	
1	0.25	0.25	1.0×10^{-2}
2	0.50	0.25	4.0×10^{-2}
3	0.50	0.50	8.0×10^{-2}

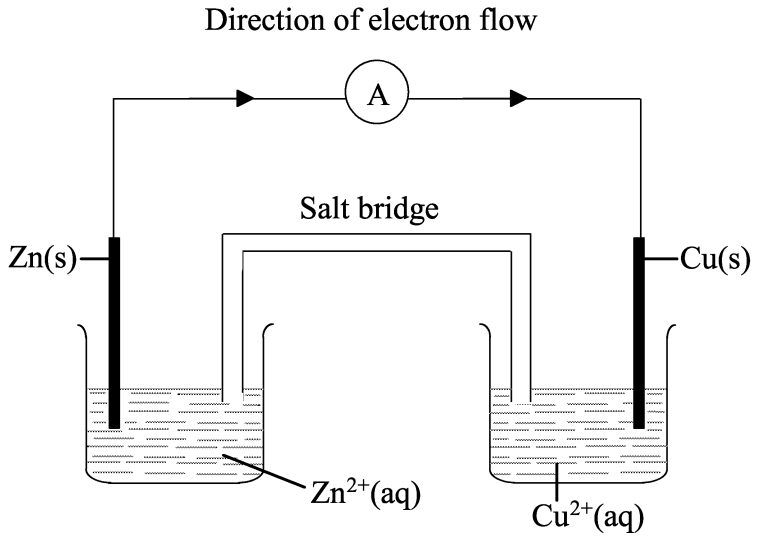
(i) Define the term *order of reaction*. *[1]*

(ii) Deduce the order of reaction with respect to **both** X and Y. Explain your reasoning. *[4]*

(iii) Write the rate expression for the reaction and calculate the rate constant, including its units. *[4]*

(iv) Calculate the initial rate of reaction when the initial concentrations of X and Y are 0.40 mol dm^{-3} and 0.60 mol dm^{-3} respectively. *[2]*

7.



(a) The apparatus shown above may be used to carry out a redox reaction.

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

(ii) Write a half-equation for the oxidation reaction. *[1]*

(iii) The above reactions are carried out under *standard conditions*. State what the standard conditions are for the cell. *[2]*

(iv) Using the Data Booklet, calculate the cell potential for the above cell. *[2]*

(v) State and explain what happens to the concentration of the copper(II) ions when the cell is producing an electric current. *[2]*

(vi) State **two** observations that could be made if the zinc rod were placed in a solution of copper(II) ions. *[2]*

(This question continues on the following page)

(Question 7 continued)

(b) The standard electrode potentials for three electrode systems are given below.

$$Ti^{3+}(aq) + e^- \rightarrow Ti^{2+}(aq) \qquad E^{\ominus} = -0.37\ V$$

$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq) \qquad E^{\ominus} = +0.77\ V$$

$$Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq) \qquad E^{\ominus} = +1.45\ V$$

(i) Using the data above, deduce which species is the best reducing agent, giving a reason in terms of electrons for your answer. *[2]*

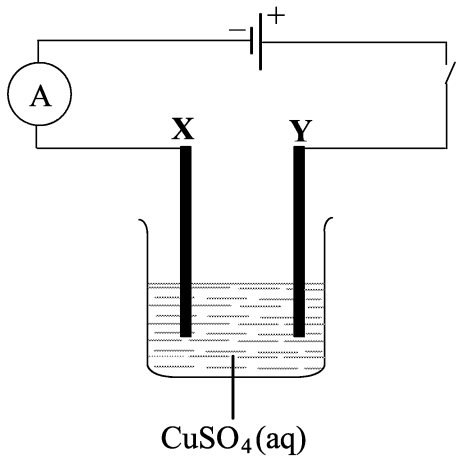
(ii) Write an equation, including state symbols, for the overall reaction with the greatest cell potential. *[2]*

(iii) State and explain the sign of $\Delta G^{\ominus}$ for the reaction in (b) (ii). *[2]*

(c) (i) State the name of a solution that would produce **only** hydrogen and oxygen when electrolyzed using platinum electrodes. *[1]*

(ii) Draw a diagram of apparatus that would allow the gases produced in the reaction in (c) (i) to be collected separately. Annotate your diagram to show the polarity of each electrode and the names and relative volumes of each gas. *[3]*

(d)



Two copper strips **X** and **Y** are placed in an aqueous solution of copper(II) sulfate and electrolyzed for a certain time. **X** was then dried and weighed.

(i) State and explain what would happen to the mass of **X**. *[3]*

(ii) State **two** ways in which the change in the mass of **X** could be increased. *[2]*

8. (a) Define the term *pH*. *[1]*

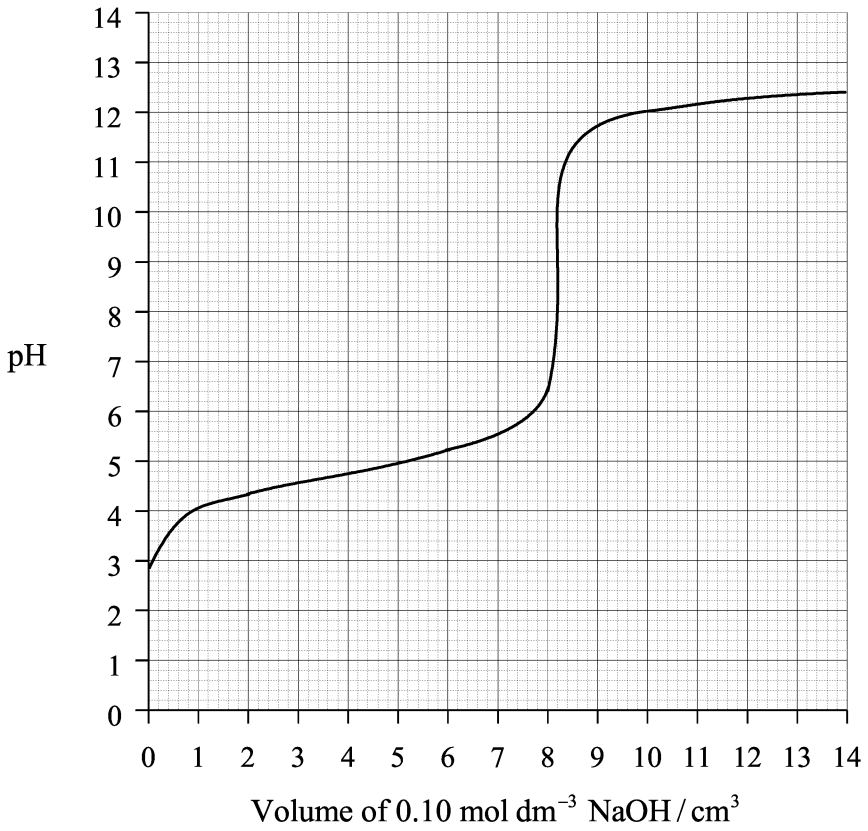
(b) Predict whether each of the following solutions would be acidic, alkaline or neutral. In each case explain your reasoning.

(i) 0.1 mol dm^{-3} $FeCl_3(aq)$

(ii) 0.1 mol dm^{-3} $NaNO_3(aq)$

(iii) 0.1 mol dm^{-3} $Na_2CO_3(aq)$ *[6]*

(c) The following graph shows how the pH changes during the titration of 10 cm^3 of a solution of a weak acid (HA) with 0.10 mol dm^{-3} NaOH.



(i) State the pH at the equivalence point and explain why the pH changes rapidly in this region. *[2]*

(ii) Calculate the initial concentration of the acid (HA). *[3]*

(iii) Calculate the $[H^+]$ of the acid before any sodium hydroxide is added. Use this value to determine the K_a value and the pK_a value of the acid. *[5]*

(This question continues on the following page)

(Question 8 continued)

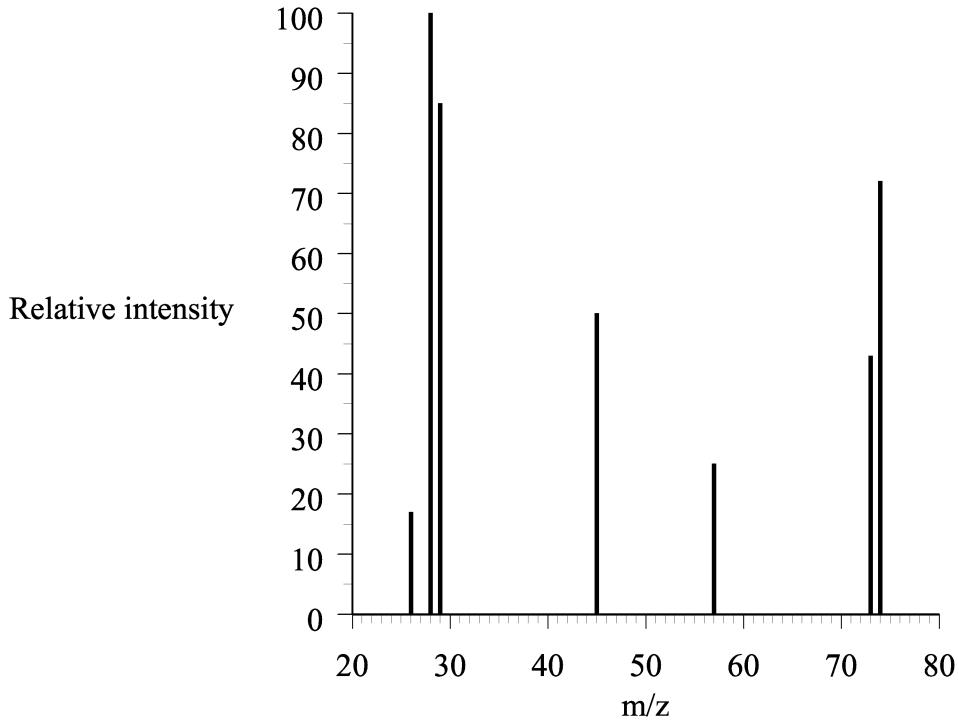
(d) A buffer solution can be made by dissolving 0.25 g of sodium ethanoate in 200 cm^3 of 0.10 mol dm^{-3} ethanoic acid. Assume that the change in volume is negligible.

(i) Define the term *buffer solution*. *[2]*

(ii) Calculate the concentration of the sodium ethanoate in mol dm^{-3}. *[3]*

(iii) Calculate the pH of the resulting buffer solution by using information from Table 16 of the Data Booklet. *[3]*

9. A pleasant-smelling liquid **A**, was hydrolysed in acid conditions to give two organic products, **B** and **C**. Product **B**, a carboxylic acid, was readily soluble in water. The mass spectrum of **B** is shown below.



(a) (i) Identify the M_r of **B**. *[1]*

(ii) Suggest fragment ions responsible for the peaks at m/z values of 29, 45 and 57. *[3]*

(iii) Using the information in (ii), deduce the structural formula of **B**. *[1]*

(b) Product **C** was also soluble in water and on analysis was found to contain

60.0 % C, 13.3 % H and 26.7 % O by mass.

The M_r of compound **C** is 60.

(i) Calculate the empirical and molecular formulas of **C**. *[3]*

(ii) Draw **three** possible structural formulas for the isomers with this molecular formula. *[3]*

(iii) Explain why **two** of the isomers in (ii) will show a broad absorption in their infrared spectra which will be missing in the spectrum of the third isomer. *[1]*

(iv) Explain how the two isomers showing the broad absorption in their infrared spectra could be identified from their ^{1}H NMR spectra. *[2]*

(c) Compound **C** was oxidised to compound **D** by refluxing with acidified sodium dichromate(VI). **D** was not acidic, but contained the **same** number of carbon atoms as **C**. Deduce the structural formulas of **C** and **D** and state the name of each one. *[4]*

(This question continues on the following page)

(Question 9 continued)

(d) Deduce the structural formula of **A**. *[1]*

(e) An alcohol **E** does not react with acidified potassium dichromate(VI) but forms an alkene, **F**, with molecular formula C_4H_8, when heated with concentrated sulfuric acid.

(i) Deduce the structures and state the names of **E** and **F**. *[4]*

(ii) Write an equation for the conversion of **E** to **F** and state the type of reaction that occurs. *[2]*
