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CHEMISTRY
HIGHER LEVEL
PAPER 2

Monday 18 May 2009 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session 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 on answer sheets. Write your session 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.

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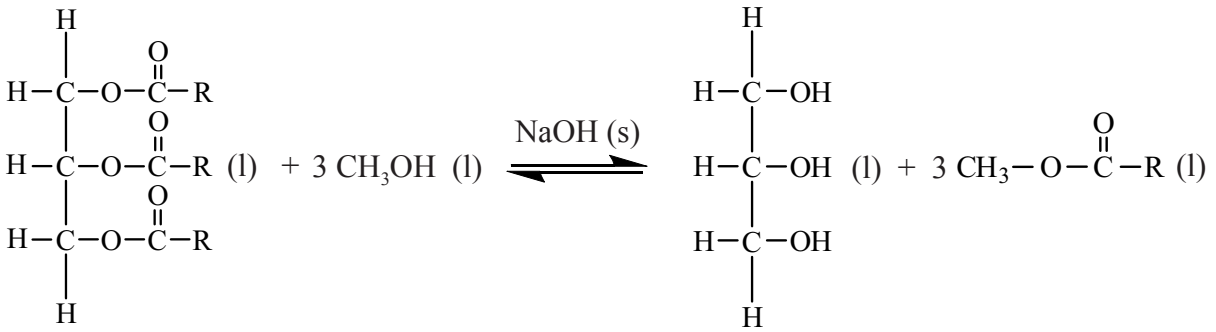
SECTION A

*Answer **all** the questions in the spaces provided.*

1. Biodiesel makes use of plants' ability to fix atmospheric carbon by photosynthesis. Many companies and individuals are now using biodiesel as a fuel in order to reduce their carbon footprint. Biodiesel can be synthesized from vegetable oil according to the following reaction.



vegetable oil methanol glycerol biodiesel

(a) Identify the organic functional group present in both vegetable oil and biodiesel. *[1]*

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(b) For part of her extended essay investigation into the efficiency of the process, a student reacted a pure sample of a vegetable oil (where $R = C_{17}H_{33}$) with methanol. The raw data recorded for the reaction is below.

Mass of oil	=	1013.0 g
Mass of methanol	=	200.0 g
Mass of sodium hydroxide	=	3.5 g
Mass of biodiesel produced	=	811.0 g

The relative molecular mass of the oil used by the student is 885.6. Calculate the amount (in moles) of the oil and the methanol used, and hence the amount (in moles) of excess methanol. *[3]*

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(Question 1 continued)

(c) The reversible arrows in the equation indicate that the production of biodiesel is an equilibrium process.

(i) State what is meant by the term *dynamic equilibrium*. *[1]*

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(ii) Using the abbreviations [vegetable oil], [methanol], [glycerol] and [biodiesel] deduce the equilibrium constant expression (K_c) for this reaction. *[1]*

(iii) Suggest a reason why excess methanol is used in this process. *[1]*

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(iv) State and explain the effect that the addition of the sodium hydroxide catalyst will have on the position of equilibrium. *[2]*

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(d) The reactants had to be stirred vigorously because they formed two distinct layers in the reaction vessel. Explain why they form two distinct layers and why stirring increases the rate of reaction. *[2]*

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(Question 1 continued)

(e) Calculate the percentage yield of biodiesel obtained in this process. *[2]*

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(f) When biodiesel is combusted it produces carbon dioxide. Explain why the use of biodiesel as a fuel does not significantly contribute to global warming. *[1]*

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2. (a) The pK_a value for propanoic acid is given in Table 15 of the Data Booklet.

(i) State the equation for the reaction of propanoic acid with water. *[1]*

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(ii) Calculate the hydrogen ion concentration (in mol dm^{-3}) of an aqueous solution of 0.100 mol dm^{-3} propanoic acid. *[2]*

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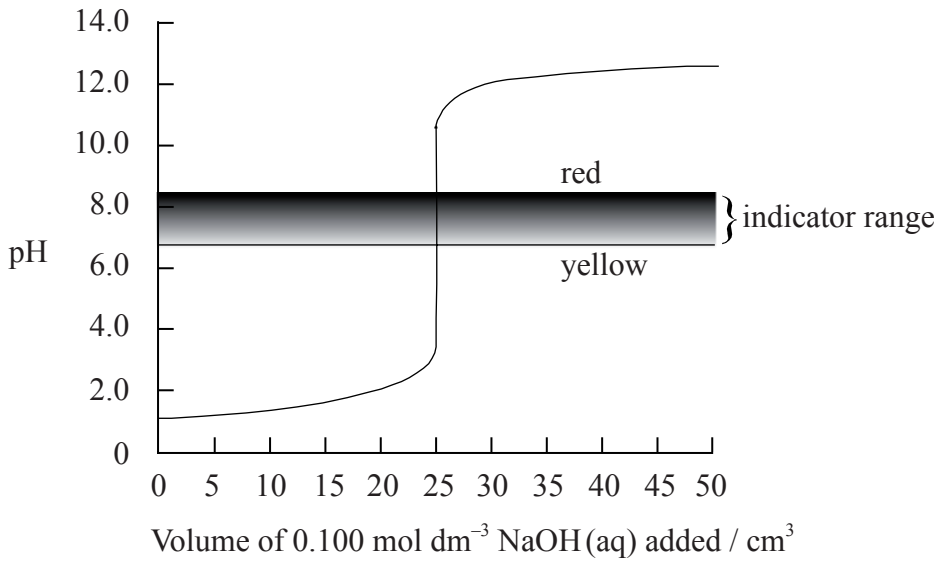
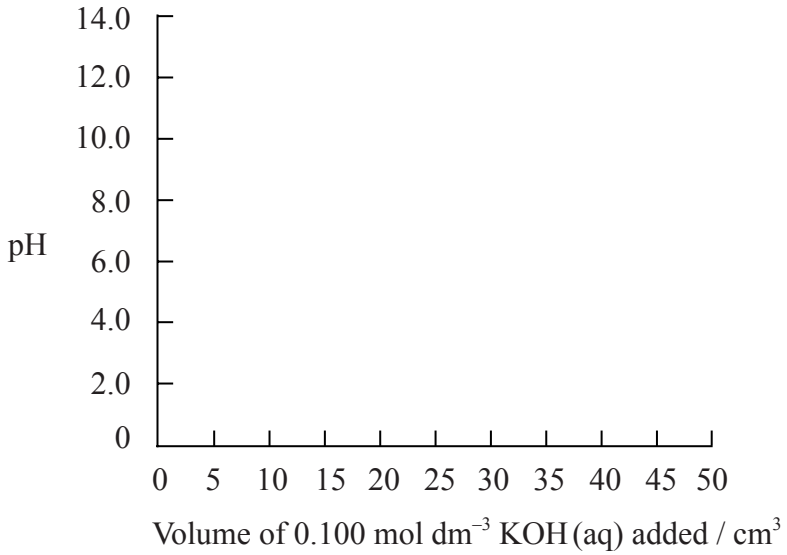
(Question 2 continued)

(b) The graph below shows a computer simulation of a titration of 25.0 cm^3 of 0.100 mol dm^{-3} hydrochloric acid with 0.100 mol dm^{-3} sodium hydroxide and the pH range of phenol red indicator.



Sketch the graph that would be obtained for the titration of 25.0 cm^3 of 0.100 mol dm^{-3} propanoic acid with 0.100 mol dm^{-3} potassium hydroxide using bromophenol blue as an indicator. (The pH range of bromophenol blue can be found in Table 16 of the Data Booklet). *[3]*



3. Two students were asked to use information from the Data Booklet to calculate a value for the enthalpy of hydrogenation of ethene to form ethane.

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$$

John used the average bond enthalpies from Table 10. Marit used the values of enthalpies of combustion from Table 12.

(a) Calculate the value for the enthalpy of hydrogenation of ethene obtained using the average bond enthalpies given in Table 10. *[2]*

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(b) Determine the value for the enthalpy of hydrogenation of ethene using the values for the enthalpies of combustion of ethene, hydrogen and ethane given in Table 12. *[2]*

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(c) Suggest **one** reason why John's answer is slightly less accurate than Marit's answer and calculate the percentage difference. *[2]*

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(Question 3 continued)

(d) John then decided to determine the enthalpy of hydrogenation of cyclohexene to produce cyclohexane.

$$C_6H_{10}(l) + H_2(g) \rightarrow C_6H_{12}(l)$$

(i) Use the average bond enthalpies to deduce a value for the enthalpy of hydrogenation of cyclohexene. *[1]*

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(ii) The percentage difference between these two methods (average bond enthalpies and enthalpies of combustion) is greater for cyclohexene than it was for ethene. John's hypothesis was that it would be the same. Determine why the use of average bond enthalpies is less accurate for the cyclohexene equation shown above, than it was for ethene. Deduce what extra information is needed to provide a more accurate answer. *[2]*

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4. The percentage of iron(II) ions, Fe^{2+}, in a vitamin tablet can be estimated by dissolving the tablet in dilute sulfuric acid and titrating with standard potassium manganate(VII) solution, $KMnO_4(aq)$. During the process iron(II) is oxidized to iron(III) and the manganate(VII) ion is reduced to the manganese(II) ion, $Mn^{2+}(aq)$. It was found that one tablet with a mass of 1.43 g required 11.6 cm^3 of 2.00×10^{-2} mol dm^{-3} $KMnO_4(aq)$ to reach the end-point.

(a) (i) State the half-equation for the oxidation of the iron(II) ions. *[1]*

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(ii) State the half-equation for the reduction of the MnO_4^- ions in acidic solution. *[1]*

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(iii) Deduce the overall redox equation for the reaction. *[1]*

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(b) (i) Calculate the amount, in moles, of MnO_4^- ions present in 11.6 cm^3 of 2.00×10^{-2} mol dm^{-3} $KMnO_4(aq)$. *[1]*

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(ii) Calculate the amount, in moles, of Fe^{2+} ions present in the vitamin tablet. *[1]*

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(iii) Determine the percentage by mass of Fe^{2+} ions present in the vitamin tablet. *[2]*

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5. Sodium oxide, Na_2O, is a white solid with a high melting point.

(a) Explain why solid sodium oxide is a non-conductor of electricity. *[1]*

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(b) Molten sodium oxide is a good conductor of electricity. State the half-equation for the reaction occurring at the positive electrode during the electrolysis of molten sodium oxide. *[1]*

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(c) (i) State the acid-base nature of sodium oxide. *[1]*

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(ii) State the equation for the reaction of sodium oxide with water. *[1]*

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SECTION B

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

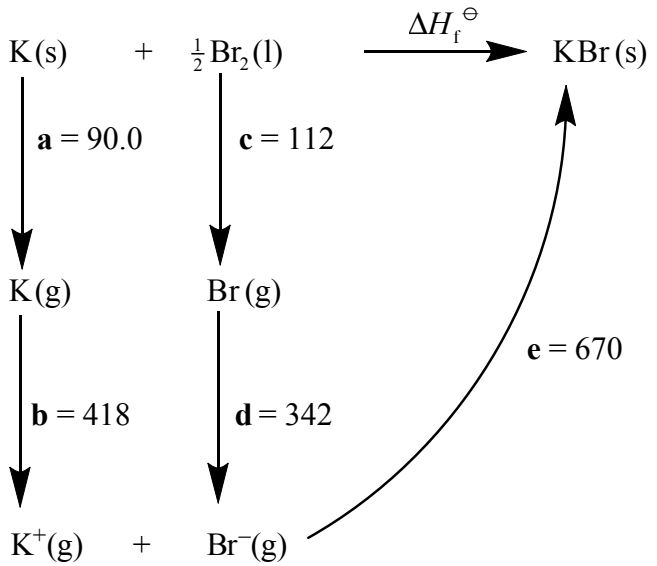
6. (a) Draw the Lewis structures, state the shape and predict the bond angles for the following species.

(i) PCl_3 *[3]*

(ii) NH_2^- *[3]*

(iii) XeF_4 *[3]*

(b) Consider the following Born-Haber cycle:



The magnitudes for each of the enthalpy changes (**a** to **e**) are given in kJ mol^{-1} but their signs (+ or –) have been omitted.

(i) State the names for the enthalpy changes **c** and **d**. *[2]*

(ii) Deduce which **two** of the enthalpy changes **a** to **e** have negative signs. *[1]*

(iii) Determine the value for the enthalpy of formation of potassium bromide. *[2]*

(iv) Explain why the quantitative value for the lattice enthalpy of calcium bromide is larger than the value for the lattice enthalpy of potassium bromide. *[2]*

(This question continues on the following page)

(Question 6 continued)

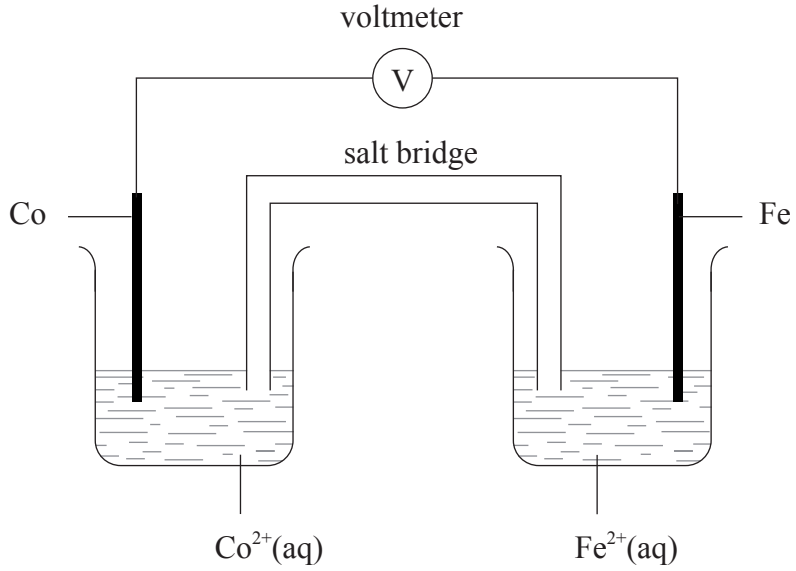
(c) (i) Compare the formation of a sigma (σ) and a pi (π) bond between two carbon atoms in a molecule. *[2]*

(ii) Identify how many sigma and pi bonds are present in propene, C_3H_6. *[2]*

(iii) Deduce all the bond angles present in propene. *[2]*

(iv) Explain how the concept of hybridization can be used to explain the bonding in the triple bond present in propyne. *[3]*

7. (a) An electrochemical cell is made from an iron half-cell connected to a cobalt half-cell:



The standard electrode potential for $Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$ is -0.45 V. The total cell potential obtained when the cell is operating under standard conditions is 0.17 V. Cobalt is produced during the spontaneous reaction.

(i) Define the term *standard electrode potential* and state the meaning of the minus sign in the value of -0.45 V. *[3]*

(ii) Calculate the value for the standard electrode potential for the cobalt half-cell. *[1]*

(iii) Deduce which species acts as the oxidizing agent when the cell is operating. *[1]*

(iv) Deduce the equation for the spontaneous reaction taking place when the iron half-cell is connected instead to an aluminium half-cell. *[2]*

(v) Explain the function of the salt bridge in an electrochemical cell. *[2]*

(b) Deduce the oxidation number of cobalt in the following species.

(i) $[Co(H_2O)_6]^{2+}$ *[1]*

(ii) $Co_2(SO_4)_3$ *[1]*

(iii) $[CoCl_4]^{2-}$ *[1]*

(This question continues on the following page)

(Question 7 continued)

(c) An electrolytic cell is made using a very dilute solution of sodium chloride.

(i) Draw a labelled diagram of the cell. Use an arrow to show the direction of the electron flow and identify the positive and negative electrodes. *[3]*

(ii) Give the formulas of all the ions present in the solution. *[2]*

(iii) Predict the products obtained at each electrode and state the half-equation for the formation of each product. *[3]*

(iv) Deduce the molar ratios of the products obtained at the two electrodes. *[1]*

(d) Predict the products by giving the relevant half-equation for the reaction occurring at each electrode if the electrolyte of the cell described in part (c) was changed to:

(i) concentrated sodium chloride *[2]*

(ii) molten sodium bromide *[2]*

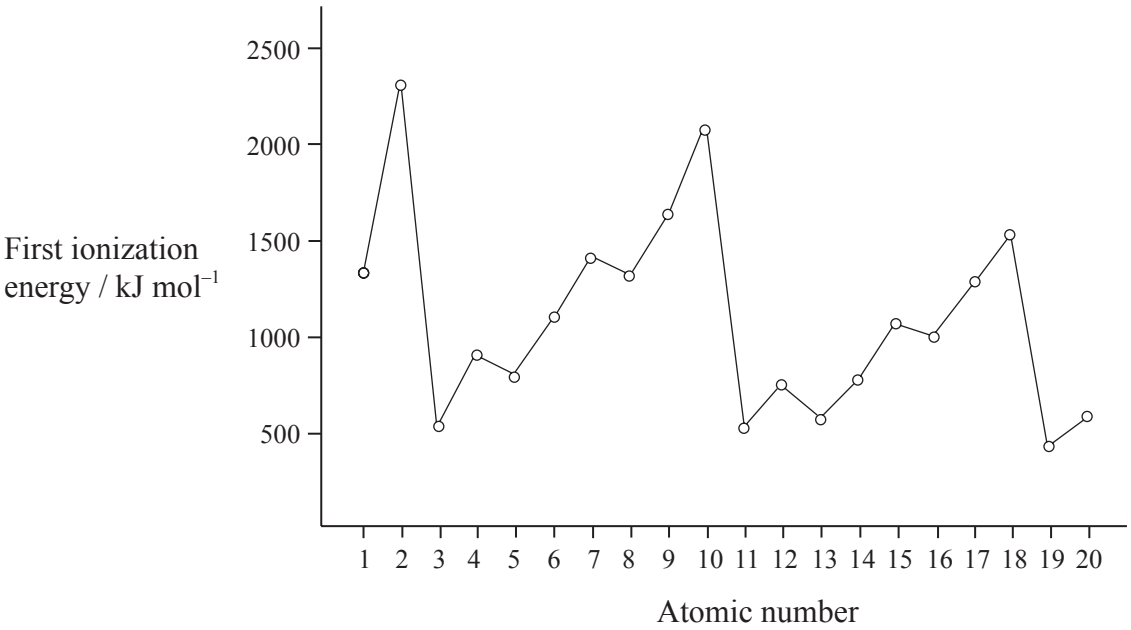
8. (a) (i) Describe and explain the operation of a mass spectrometer. *[5]*

(ii) State **three** factors that affect the degree of deflection of ions in a mass spectrometer. *[3]*

(iii) Strontium exists as four naturally-occurring isotopes. Calculate the relative atomic mass of strontium to two decimal places from the following data. *[2]*

Isotope	Percentage abundance
Sr-84	0.56
Sr-86	9.90
Sr-87	7.00
Sr-88	82.54

(b) The graph of the first ionization energy plotted against atomic number for the first twenty elements shows periodicity.



(i) Define the term *first ionization energy* and state what is meant by the term *periodicity*. *[2]*

(ii) Explain how information from this graph provides evidence for the existence of main energy levels and sub-levels within atoms. *[4]*

(iii) State what is meant by the term *second ionization energy*. *[1]*

(This question continues on the following page)

(Question 8 continued)

(iv) Sketch and explain the shape of the graph obtained for the successive ionization energies of potassium using a logarithmic scale for ionization energy on the *y*-axis against number of electrons removed on the *x*-axis. *[4]*

(c) (i) State the **full** electronic configurations of copper, Cu, and the copper(I) ion, Cu^+. *[2]*

(ii) Explain why copper(II) compounds in aqueous solution are coloured whereas scandium(III) compounds in aqueous solution are colourless. *[2]*

9. (a) But-1-ene and 1-aminobutane (1-butylamine) can both be prepared from 1-bromobutane.

(i) State the equation (using structural formulas) and the necessary reagents and conditions for the preparation of but-1-ene from 1-bromobutane. *[3]*

(ii) Identify the type of reaction and explain the mechanism for the preparation of but-1-ene from 1-bromobutane using curly arrows to represent the movement of electron pairs. *[3]*

(iii) State the equation (using structural formulas) for the preparation of 1-aminobutane from 1-bromobutane. State the necessary reagents and conditions of the reaction. *[3]*

(iv) Explain the mechanism for the preparation of 1-aminobutane from 1-bromobutane using curly arrows to represent the movement of electron pairs. *[4]*

(b) 2-bromobutane and 2-bromo-2-methylpropane are two isomers of 1-bromobutane.

(i) Draw the structures of the two mirror images of the isomer that can exhibit optical isomerism. *[2]*

(ii) Describe how the two optical isomers can be distinguished practically using plane-polarized light. *[2]*

(iii) Explain why the mechanism of the reaction will be different if 1-bromobutane is replaced by 2-bromo-2-methylpropane to form 2-amino-2-methylpropane in the reaction in part (a) (iv). *[3]*

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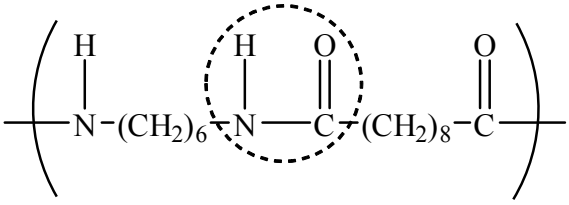
(Question 9 continued)

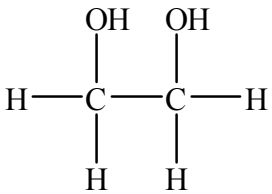
(c) One form of nylon has the repeating unit:



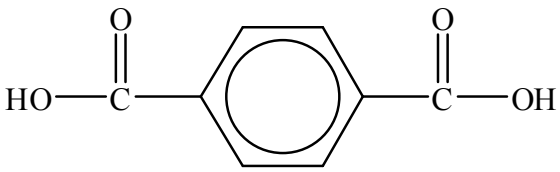
(i) Identify the circled functional group. *[1]*

(ii) Deduce the structures of the two monomers used to make this form of nylon. *[2]*

(iii) Nylon is a condensation polymer. Another condensation polymer can be formed by reacting ethane-1,2-diol with benzene-1,4-dicarboxylic acid.



ethane-1,2-diol



benzene-1,4-dicarboxylic acid

Deduce the equation for this reaction using n moles of each reactant. *[2]*