Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Thursday 14 May 2015 (afternoon)

Candidate session number

1 hour 15 minutes

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 questions.
- Section B: answer one question.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

2215–6111

17 pages

Section A

Answer **all** questions. Write your answers in the boxes provided.

1. Ethanedioic acid is a diprotic acid. A student determined the value of x in the formula of hydrated ethanedioic acid, $HOOC–COOH•xH_2O$, by titrating a known mass of the acid with a 0.100 mol dm^{-3} solution of NaOH (aq).

0.795 g of ethanedioic acid was dissolved in distilled water and made up to a total volume of 250 cm^3 in a volumetric flask.

25 cm^3 of this ethanedioic acid solution was pipetted into a flask and titrated against aqueous sodium hydroxide using phenolphthalein as an indicator.

The titration was then repeated twice to obtain the results below.

Volume of 0.100 mol dm^{-3} NaOH / cm^3	**Titration 1**	**Titration 2**	**Titration 3**
Final burette reading (± 0.05)	13.00	25.70	38.20
Initial burette reading (± 0.05)	0.00	13.00	25.70
Volume added			

(a) State the uncertainty of the volume of NaOH added in cm^3. [1]

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(b) Calculate the average volume of NaOH added, in cm^3, in titrations 2 and 3, and then calculate the amount, in mol, of NaOH added. [2]

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(This question continues on the following page)

(Question 1 continued)

(c) (i) The equation for the reaction taking place in the titration is:

$$HOOC–COOH(aq) + 2NaOH(aq) \rightarrow NaOOC–COONa(aq) + 2H_2O(l)$$

Determine the amount, in mol, of ethanedioic acid that reacts with the average volume of NaOH (aq). [1]

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(ii) Determine the amount, in mol, of ethanedioic acid present in 250 cm^3 of the original solution. [1]

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(iii) Determine the molar mass of hydrated ethanedioic acid. [1]

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(iv) Determine the value of x in the formula $HOOC–COOH•xH_2O$. [2]

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(d) Identify the strongest intermolecular force in solid ethanedioic acid. [1]

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(This question continues on the following page)

(Question 1 continued)

(e) Deduce the Lewis (electron dot) structure of ethanedioic acid, HOOC–COOH. [1]

2. Bromomethane was used as a pesticide until it was found to be ozone-depleting.

(a) State the equation for the reaction between methane and bromine to form bromomethane. [1]

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(b) Explain, using equations, the complete free-radical mechanism for the reaction of methane with bromine, including necessary reaction conditions. [4]

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(c) Bromine can be produced by the electrolysis of **molten** sodium bromide. Deduce the half-equation for the reaction at each electrode. [2]

Positive electrode (anode):

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Negative electrode (cathode):

. . . . . .

(d) Bromine reacts with aqueous sodium iodide:

$$Br_2(aq) + 2NaI(aq) \rightarrow I_2(aq) + 2NaBr(aq)$$

Identify the oxidizing agent in this reaction. [1]

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3. The rate of reaction is an important factor in industrial processes such as the Contact process to make sulfur trioxide, $SO_3(g)$.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H^{\ominus} = -198\,kJ$$

(a) Define the term *rate of reaction*. [1]

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(b) Describe the collision theory. [3]

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4. (a) State the relative mass and charge of the subatomic particles of an atom. [2]

	Relative mass	Relative charge
Proton	. . . . .	+1
Electron	5×10^{-4}	. . . . .
Neutron	. . . . .	. . . . .

(b) (i) Calculate the number of neutrons and electrons in one atom of ^{65}Cu. [1]

Neutrons:

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Electrons:

. . . . . .

(ii) State one difference in the physical properties of the isotopes ^{63}Cu and ^{65}Cu and explain why their chemical properties are the same. [2]

Physical:

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Chemical:

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(c) Describe the bonding in solid copper. [2]

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(This question continues on the following page)

(Question 4 continued)

(d) Suggest **two** properties of copper that make it useful and economically important. [1]

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Section B

Answer **one** question. Write your answers in the boxes provided.

5. Ethanol has many industrial uses.

(a) (i) State an equation for the formation of ethanol from ethene and the necessary reaction conditions. [3]

Equation:

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Conditions:

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(ii) Deduce the volume of ethanol, in dm^3, produced from 1.5 dm^3 of ethene, assuming both are gaseous and at the same temperature and pressure. [1]

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(b) (i) Define the term *average bond enthalpy*. [2]

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(This question continues on the following page)

(Question 5 continued)

(ii) Ethanol can be used as a fuel. Determine the enthalpy of combustion of ethanol at 298 K, in $kJ\,mol^{-1}$, using the values in table 10 of the data booklet, assuming all reactants and products are gaseous. [4]

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(iii) Suggest why the value of the enthalpy of combustion of ethanol quoted in table 12 of the data booklet is different to that calculated using bond enthalpies. [1]

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(iv) Explain why the reaction is exothermic in terms of the bonds involved. [1]

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(c) Identify the homologous series to which ethanol belongs and state **two** features of a homologous series. [3]

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(This question continues on the following page)

(Question 5 continued)

(d) Describe an experiment that could be carried out to measure the enthalpy of combustion of ethanol in the laboratory using calorimetry. Your answer should include the measurements you would make and the calculations you would perform. [5]

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6. Across period 3, elements increase in atomic number, decrease in atomic radius and increase in electronegativity.

(a) Define the term *electronegativity*. [1]

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(b) Explain why the atomic radius of elements decreases across the period. [2]

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(c) (i) State the equations for the reactions of sodium oxide with water and phosphorus(V) oxide with water. [2]

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(ii) Suggest the pH of the solutions formed in part (c) (i). [2]

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(Question 6 continued)

(d) Describe **three** tests that can be carried out in the laboratory, and the expected results, to distinguish between 0.10 mol dm^{-3} HCl (aq) and 0.10 mol dm^{-3} CH_3COOH (aq). [3]

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(e) Explain whether BF_3 can act as a Brønsted–Lowry acid, a Lewis acid or both. [2]

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(f) (i) Describe the bonding and structure of sodium chloride. [2]

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(ii) State the formula of the compounds formed between the elements below. [2]

Sodium and sulfur:

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Magnesium and phosphorus:

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(This question continues on the following page)

(Question 6 continued)

(g) Covalent bonds form when phosphorus reacts with chlorine to form PCl_3. Deduce the Lewis (electron dot) structure, the shape and bond angle in PCl_3 and explain why the molecule is polar. [4]

Lewis (electron dot) structure:

Name of shape:

. . . . . .

Bond angle:

. . . . . .

Explanation of polarity of molecule:

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7. (a) A hydrocarbon has the empirical formula C_3H_7. When 1.17 g of the compound is heated to 85 °C at a pressure of 101 kPa it occupies a volume of 400 cm^3.

(i) Calculate the molar mass of the compound, showing your working. [3]

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(ii) Deduce the molecular formula of the compound. [1]

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(b) C_5H_{12} exists as three isomers. Identify the structure of the isomer with the **lowest** boiling point and explain your choice. [2]

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(Question 7 continued)

(c) (i) Ethanol is a primary alcohol that can be oxidized by acidified potassium dichromate(VI). Distinguish between the reaction conditions needed to produce ethanal and ethanoic acid. [2]

Ethanal:

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Ethanoic acid:

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(ii) Determine the oxidation number of carbon in ethanol and ethanal. [2]

Ethanol:

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Ethanal:

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(iii) Deduce the half-equation for the oxidation of ethanol to ethanal. [1]

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(iv) Deduce the overall redox equation for the reaction of ethanol to ethanal with acidified potassium dichromate(VI) by combining your answer to part (c) (iii) with the following half-equation:

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$ [2]

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(This question continues on the following page)

(Question 7 continued)

(d) (i) Describe **two** characteristics of a reaction at equilibrium. [2]

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(ii) Describe how a catalyst increases the rate of a reaction. [2]

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(iii) State and explain the effect of a catalyst on the position of equilibrium. [2]

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(e) Ethanoic acid reacts with ethanol to form the ester ethyl ethanoate.

$$CH_3COOH(l) + CH_3CH_2OH(l) \overset{H^+}{\rightleftharpoons} CH_3COOCH_2CH_3(l) + H_2O(l)$$

The esterification reaction is exothermic. State the effect of increasing temperature on the value of the equilibrium constant (K_c) for this reaction. [1]

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