

**Chemistry**  
**Standard level**  
**Paper 2**

Thursday 14 May 2015 (afternoon)

Candidate session number

1 hour 15 minutes

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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 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]**.



### 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,  $\text{HOOC}-\text{COOH}\cdot x\text{H}_2\text{O}$ , by titrating a known mass of the acid with a  $0.100 \text{ mol dm}^{-3}$  solution of  $\text{NaOH}(\text{aq})$ .

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

$25 \text{ cm}^3$  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 $0.100 \text{ mol dm}^{-3}$ $\text{NaOH} / \text{cm}^3$	Titration 1	Titration 2	Titration 3
Final burette reading ( $\pm 0.05$ )	13.00	25.70	38.20
Initial burette reading ( $\pm 0.05$ )	0.00	13.00	25.70
Volume added			

- (a) State the uncertainty of the volume of  $\text{NaOH}$  added in  $\text{cm}^3$ . [1]

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

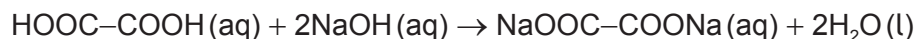
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**(Question 1 continued)**

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



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<sup>3</sup> 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<sub>2</sub>O. [2]

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

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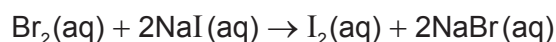
(b) Explain, using equations, the complete free-radical mechanism for the reaction of methane with bromine, including necessary reaction conditions. [4]

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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):  
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(d) Bromine reacts with aqueous sodium iodide:

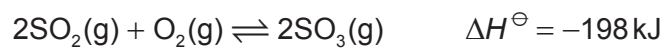


Identify the oxidizing agent in this reaction. [1]

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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,  $\text{SO}_3(\text{g})$ .



- (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	$5 \times 10^{-4}$	.....
Neutron	.....	.....

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

Neutrons:  
.....

Electrons:  
.....

- (ii) State one difference in the physical properties of the isotopes  $^{63}\text{Cu}$  and  $^{65}\text{Cu}$  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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(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  $\text{dm}^3$ , produced from  $1.5 \text{ dm}^3$  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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**(Question 5 continued)**

- (ii) Ethanol can be used as a fuel. Determine the enthalpy of combustion of ethanol at 298 K, in  $\text{kJ mol}^{-1}$ , 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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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  $0.10 \text{ mol dm}^{-3} \text{ HCl (aq)}$  and  $0.10 \text{ mol dm}^{-3} \text{ CH}_3\text{COOH (aq)}$ . [3]

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- (e) Explain whether  $\text{BF}_3$  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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**(Question 6 continued)**

- (g) Covalent bonds form when phosphorus reacts with chlorine to form  $\text{PCl}_3$ . Deduce the Lewis (electron dot) structure, the shape and bond angle in  $\text{PCl}_3$  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  $85^\circ\text{C}$  at a pressure of 101 kPa it occupies a volume of  $400\text{ cm}^3$ .

(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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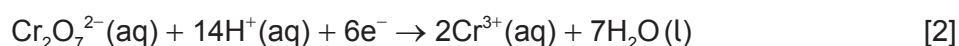
Ethanal:

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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:



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## (Question 7 continued)

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

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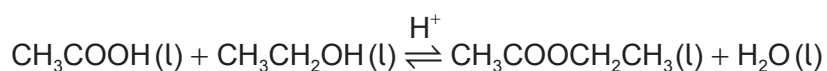
- (ii) Describe how a catalyst increases the rate of a reaction. [2]

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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.



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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