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**Pearson Edexcel GCE**

| Centre Number | Candidate Number |
|---|---|
| | |

# Chemistry

## Advanced Subsidiary

## Paper 2: Core Organic and Physical Chemistry

Friday 10 June 2016 – Afternoon
**Time: 1 hour 30 minutes**

Paper Reference
**8CH0/02**

**You must have:**
Data Booklet
Scientific calculator, ruler

Total Marks

### Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

### Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- For questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.

### Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

*Turn over* ▶

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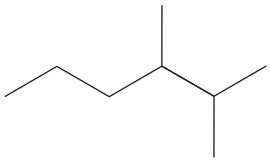
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**Answer ALL questions.**

**Some questions must be answered with a cross in a box ☒.**
**If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

**1** Alkanes are a homologous series of hydrocarbons.

(a) What is the name of this compound?



**(1)**

☒ **A** 1,1,2-trimethylpentane

☒ **B** 2,3-dimethylhexane

☒ **C** 4,5-dimethylhexane

☒ **D** 4,5,5-trimethylpentane

(b) The number of structural isomers with the molecular formula $C_5H_{12}$ is

**(1)**

☒ **A** 3

☒ **B** 4

☒ **C** 5

☒ **D** 6

(c) Write the equation for reforming heptane into cycloheptane, showing the **skeletal** formulae of the organic molecules.

**(2)**

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(d) Ethane reacts with chlorine in the presence of ultraviolet light to form a mixture of products.

(i) In the initiation step, chlorine molecules are converted into radicals.

$$Cl_2 \rightarrow 2Cl^{\bullet}$$

Identify the type of bond broken and the type of bond fission occurring in this step.

**(1)**

| | Bond broken | Bond fission |
|---|---|---|
| ☒ **A** | $\pi$ | heterolytic |
| ☒ **B** | $\sigma$ | heterolytic |
| ☒ **C** | $\pi$ | homolytic |
| ☒ **D** | $\sigma$ | homolytic |

(ii) Write the propagation steps to show the formation of $C_2H_5Cl$.

**(2)**

(iii) State how some butane, $C_4H_{10}$, is formed in the reaction.

**(1)**

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**(Total for Question 1 = 8 marks)**

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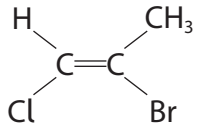
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**2** Compounds with a carbon–carbon double bond are unsaturated.

(a) What is the name of the compound shown?




**(1)**

☒ **A** *cis*-2-bromo-1-chloroprop-1-ene

☒ **B** *E*-2-bromo-1-chloroprop-1-ene

☒ **C** *trans*-2-bromo-1-chloroprop-1-ene

☒ **D** *Z*-2-bromo-1-chloroprop-1-ene

(b) Ethene reacts with bromine in the dark.

(i) What is the classification of the mechanism for the reaction between ethene and bromine?

**(1)**

☒ **A** electrophilic addition

☒ **B** electrophilic substitution

☒ **C** nucleophilic addition

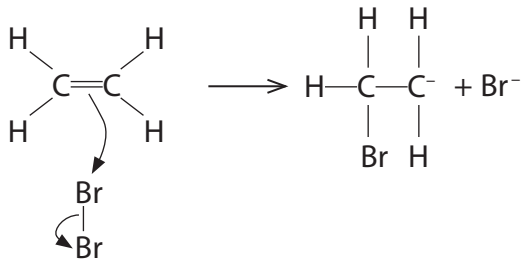
☒ **D** nucleophilic substitution

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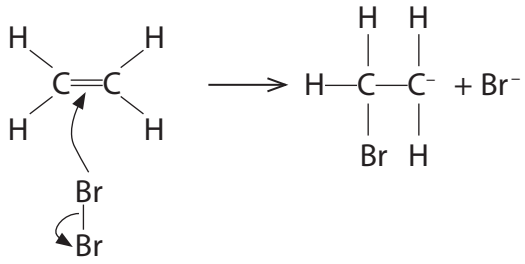
(ii) Which of the following shows the formation of the intermediate in the mechanism for the reaction between ethene and bromine?

**(1)**

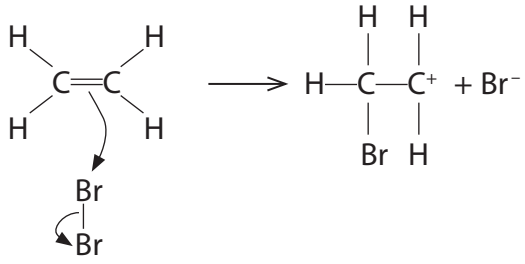
☒ **A**



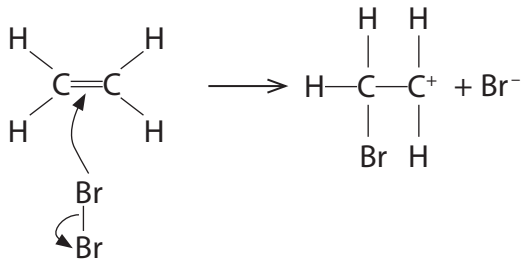
☒ **B**



☒ **C**



☒ **D**



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(c) Ethene reacts with steam to form ethanol in a reversible reaction.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \quad \Delta H = -45 \text{ kJ mol}^{-1}$$

At 300 °C and a pressure of 65 atm, the equilibrium yield of ethanol is 5%.

(i) State the effect, if any, on the yield of ethanol when the temperature is **increased**.

**(1)**

.....

.....

(ii) State the effect, if any, on the yield of ethanol when the pressure is **decreased**.

**(1)**

.....

.....

(iii) What is the expression for the equilibrium constant, $K_c$, for this reaction?

**(1)**

☒ **A** $\dfrac{[C_2H_4(g)]+[H_2O(g)]}{[C_2H_5OH(g)]}$

☒ **B** $\dfrac{[C_2H_4(g)][H_2O(g)]}{[C_2H_5OH(g)]}$

☒ **C** $\dfrac{[C_2H_5OH(g)]}{[C_2H_4(g)]+[H_2O(g)]}$

☒ **D** $\dfrac{[C_2H_5OH(g)]}{[C_2H_4(g)][H_2O(g)]}$

**(Total for Question 2 = 6 marks)**

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**3** This question is about halogenoalkanes and kinetics.

(a) Some halogenoalkanes are hydrolysed by aqueous potassium hydroxide.

(i) Write the **ionic** equation for the hydrolysis of 2-bromobutane showing the **structural** formulae for the organic molecules.

**(1)**

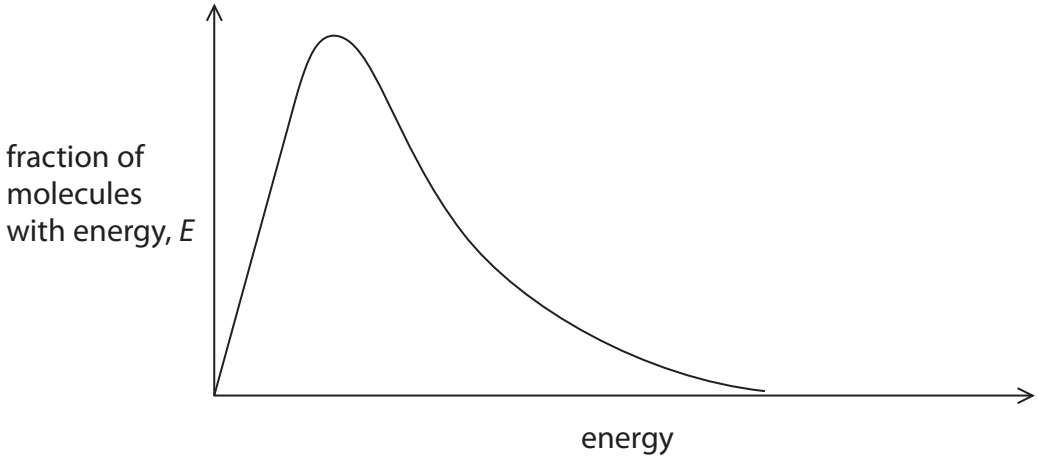
*(ii) Devise an experiment to compare the rates of hydrolysis of 2-chlorobutane, 2-bromobutane and 2-iodobutane.

State the trend in the rates of reaction. Justify your answer.

**(6)**

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(b) The graph shows the Maxwell-Boltzmann distribution of molecular energies of a gaseous system.




(i) On the graph, draw the Maxwell-Boltzmann distribution for the same system at a higher temperature.

**(1)**

(ii) Use the graph to explain why a small increase in temperature results in a large increase in the rate of a gaseous reaction.

**(3)**

**(Total for Question 3 = 11 marks)**

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**4** Ethanol, $C_2H_5OH$, is a member of the homologous series of alcohols.

(a) Calculate the number of molecules in 55.2 kg of ethanol.

[Avogadro Constant = $6.02 \times 10^{23}$ $mol^{-1}$]

**(2)**

(b) Write the equation to represent the standard enthalpy change of formation of ethanol. Include state symbols.

**(2)**

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(c) Ethanol burns completely in excess oxygen.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

(i) The table shows some mean bond enthalpy data.

| **Bond** | C—C | C—H | C—O | O—H | O═O | C═O |
|---|---|---|---|---|---|---|
| **Mean bond enthalpy / kJ mol$^{-1}$** | 347 | 413 | 358 | 464 | 498 | 805 |

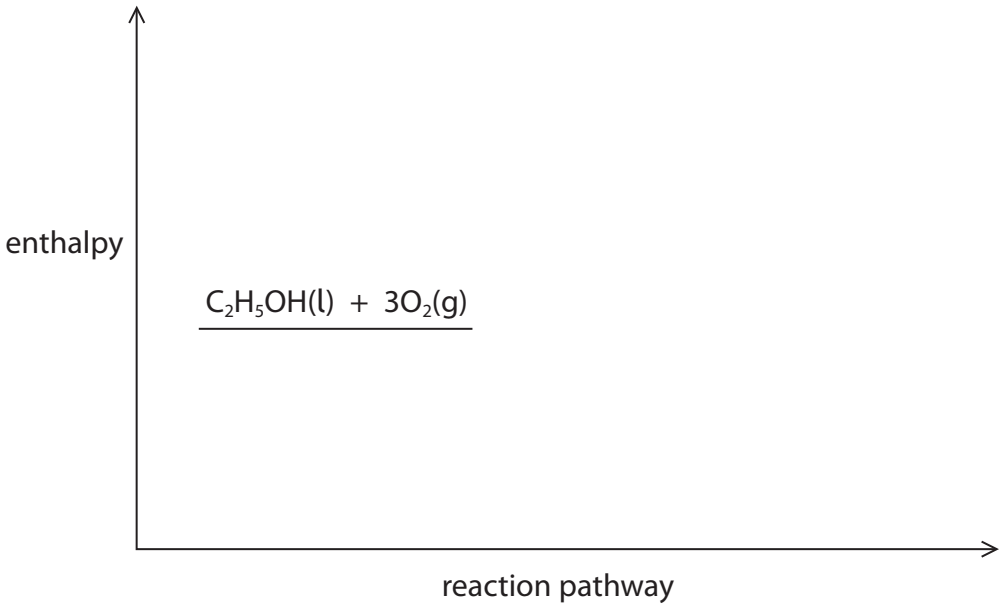
Calculate the enthalpy change, in kJ mol$^{-1}$, for the complete combustion of 1 mol of ethanol.

**(3)**

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(ii) Complete the reaction profile diagram for the combustion of ethanol and fully label the diagram.

**(2)**




(iii) A data book value for the standard enthalpy change of combustion of ethanol is $-1367.3$ kJ $mol^{-1}$.

Give the **main** reason why the value you calculated in (b)(i) is different from this data book value.

**(1)**

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**(Total for Question 4 = 10 marks)**

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**5** The following procedure may be used to prepare 2-chloro-2-methylpropane.

**Step 1** Place 15 $cm^3$ of 2-methylpropan-2-ol in a separating funnel and slowly add 30 $cm^3$ of concentrated hydrochloric acid (an excess), while swirling the funnel.

**Step 2** When all the hydrochloric acid has been added, leave the mixture to stand for 20 minutes, shaking it gently at intervals.

**Step 3** Once the organic and aqueous layers have completely separated, discard the aqueous layer.

**Step 4** Add saturated sodium hydrogencarbonate solution, a little at a time, to the organic layer. After each addition, invert the separating funnel and open the tap.

**Step 5** Discard the aqueous layer.

**Step 6** Transfer the organic layer to a small flask, add a solid drying agent and swirl the flask.

**Step 7** Decant the liquid into a clean flask and distil it to collect pure 2-chloro-2-methylpropane.

Some data on the organic reactant and product are given in the table.

| Data | 2-methylpropan-2-ol | 2-chloro-2-methylpropane |
|---|---|---|
| molar mass / g $mol^{-1}$ | 74.0 | 92.5 |
| boiling temperature / °C | 82 | 51 |
| density / g $cm^{-3}$ | 0.79 | 0.84 |

(a) Draw a diagram of a separating funnel, labelling the aqueous layer and the layer of 2-chloro-2-methylpropane that would be observed at the end of **Step 2**.

**(2)**

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(b) Give the reason why sodium hydrogencarbonate solution is added to the organic layer in **Step 4** and why it is important to open the tap after adding this solution.

**(2)**

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(c) Which one of these anhydrous compounds may be used as a drying agent in **Step 6**?

**(1)**

☒ **A** sodium chloride

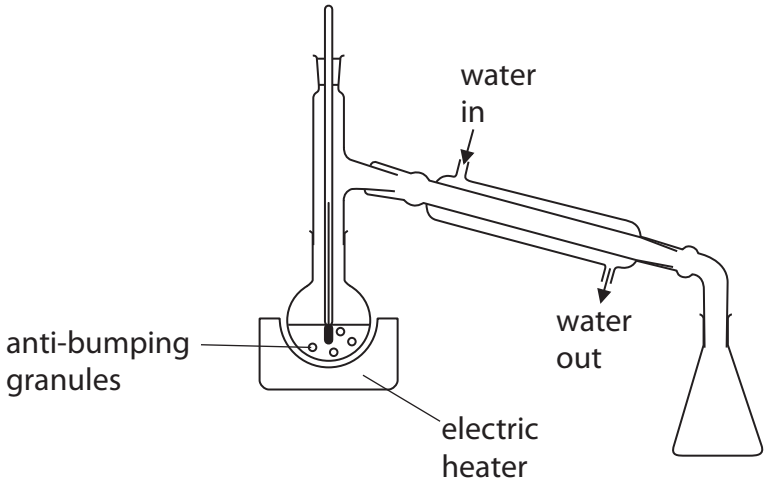
☒ **B** sodium hydroxide

☒ **C** sodium nitrate

☒ **D** sodium sulfate

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(d) A student set up this apparatus for distillation in **Step 7** as shown.




(i) Describe **three** ways in which this apparatus must be modified for safe and efficient use. Assume the apparatus is suitably clamped.

**(3)**

(ii) Give a suitable temperature range over which to collect the final product during the distillation.

**(1)**

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(e) In the preparation, 15 $cm^3$ of 2-methylpropan-2-ol produced 6.9 $cm^3$ of 2-chloro-2-methylpropane.

The equation for the reaction is

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

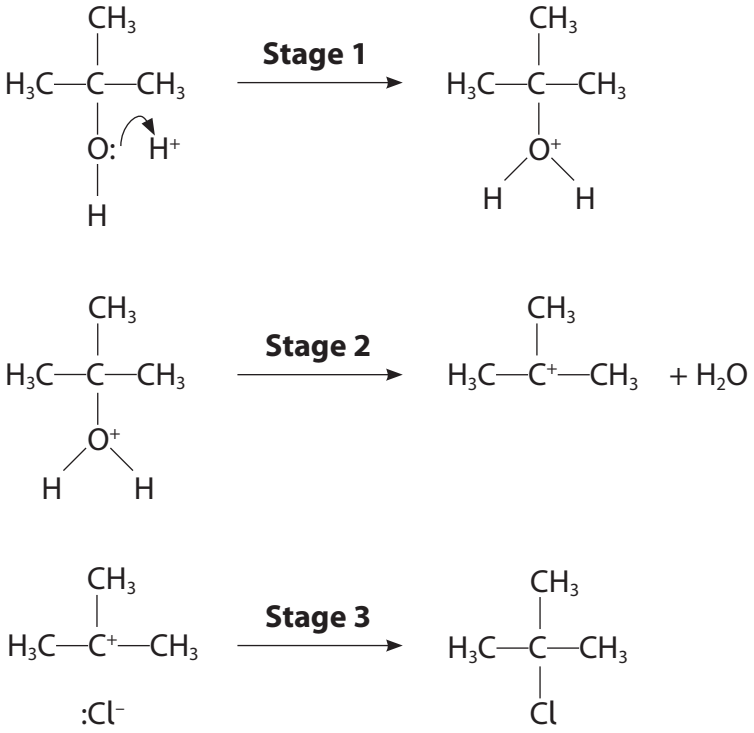
Calculate the percentage yield of 2-chloro-2-methylpropane, using data from the table.

| Data | 2-methylpropan-2-ol | 2-chloro-2-methylpropane |
|---|---|---|
| molar mass / g $mol^{-1}$ | 74.0 | 92.5 |
| boiling temperature / °C | 82 | 51 |
| density / g $cm^{-3}$ | 0.79 | 0.84 |

**(3)**

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(f) The mechanism for the reaction is in three stages.




Add curly arrows to the reactants in **Stages 2** and **3** to complete the mechanism.

**(2)**

**(Total for Question 5 = 14 marks)**

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**6** A student carries out two experiments to determine the enthalpy change that occurs when anhydrous sodium carbonate reacts to form hydrated sodium carbonate.

$$Na_2CO_3(s) + 10H_2O(l) \rightarrow Na_2CO_3.10H_2O(s)$$

(a) In the first experiment, the student determines the enthalpy change of solution for anhydrous sodium carbonate.

50.0 g of distilled water is placed in a polystyrene cup and the temperature is recorded.

A sample of anhydrous sodium carbonate is added to the water, the mixture is stirred and the final temperature recorded.

The results for this experiment are shown in the table.

| | |
|---|---|
| **mass used / g** | 5.09 |
| **initial temperature / °C** | 27.0 |
| **final temperature / °C** | 32.4 |

Calculate the enthalpy change of solution, in kJ $mol^{-1}$, for anhydrous sodium carbonate.
Give your answer to an appropriate number of significant figures and include a sign.

[Use 4.18 J $g^{-1}$ $°C^{-1}$ as the specific heat capacity of water]

$$Na_2CO_3(s) + aq \rightarrow Na_2CO_3(aq)$$

**(4)**

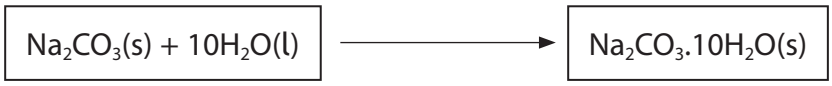
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(b) In the second experiment, the student determines the enthalpy change of solution for hydrated sodium carbonate.

$$Na_2CO_3.10H_2O(s) + aq \rightarrow Na_2CO_3(aq) \qquad \Delta H = +53.7\,kJ\,mol^{-1}$$

Complete the Hess cycle and, together with your answer to (a) calculate the enthalpy change when anhydrous sodium carbonate reacts to form hydrated sodium carbonate. Include a sign in your answer.

**(2)**




(c) Hydrated sodium carbonate slowly loses some water of crystallisation when left in air.

Explain how the enthalpy change in the second experiment would compare with the data book value if an old sample of hydrated sodium carbonate had been used.

**(2)**

**(Total for Question 6 = 8 marks)**

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**7** This question is about the identification of an alcohol, **X**.

(a) Alcohol **X** has the following percentage composition by mass:

carbon, C = 68.2%

hydrogen, H = 13.6%

oxygen, O = 18.2%

The molecular ion peak in the mass spectrum for alcohol **X** occurs at $m/z = 88$.

Use all of these data to show that the molecular formula for alcohol **X** is $C_5H_{12}O$.
Include your working.

**(2)**

(b) (i) When alcohol **X** is oxidised, a carboxylic acid is formed.

State what information this gives about alcohol **X**.

**(1)**

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(ii) Draw the **displayed** formulae of the four possible structural isomers that could be alcohol **X**.

**(3)**

| Alcohol 1 | Alcohol 2 |
|---|---|
| | |
| **Alcohol 3** | **Alcohol 4** |
| | |

(iii) The mass spectrum of alcohol **X** has a major peak at $m/z = 45$.

Draw the structure of the species that could give this peak.

**(1)**

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(iv) Alcohol **X** has a branched chain.

Identify alcohol **X**, explaining your reasoning.

**(2)**

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**(Total for Question 7 = 9 marks)**

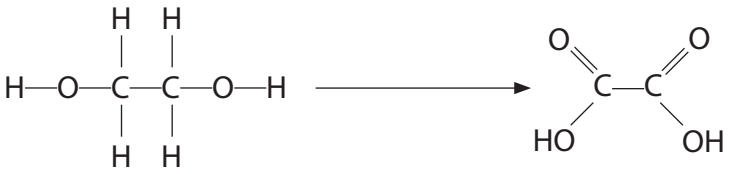
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**8** Ethanedioic acid has two carboxylic acid groups.

(a) Ethanedioic acid, $H_2C_2O_4$, can be prepared from ethane-1,2-diol.




Give the reagents and condition required for this reaction.

**(2)**

Reagents .....

Condition .....

(b) The formula for ethanedioic acid crystals is $H_2C_2O_4.nH_2O$.

To determine the number of moles of water of crystallisation, n, in 1 mol of ethanedioic acid crystals, a student carried out the following procedure.

- Prepare 250.0 $cm^3$ of a solution containing a known mass of about 1 g of ethanedioic acid crystals.
- Titrate 25.0 $cm^3$ portions of the ethanedioic acid solution with 0.103 mol $dm^{-3}$ sodium hydroxide solution, using phenolphthalein as indicator.

The student obtained these results:

mass of ethanedioic acid crystals = 1.09 g

mean titre = 16.20 $cm^3$

The equation for the reaction is

$$H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$$

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(i) Describe how the student should prepare the 250.0 $cm^3$ of ethanedioic acid solution.

**(4)**

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(ii) Give the colour change at the end-point in this titration.

**(1)**

From ..... to .....

(iii) Calculate a value of n in the formula $H_2C_2O_4.nH_2O$ from these data.

**(5)**

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(iv) The student thought that the ethanedioic acid crystals used may have been slightly damp.

Explain the effect of using damp crystals on the titre and on the value of n.

**(2)**

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**(Total for Question 8 = 14 marks)**

**TOTAL FOR PAPER = 80 MARKS**

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# The Periodic Table of Elements

| 1 | 2 | | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 0 (8) (18) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1.0 H hydrogen 1 | | | | | | | | | | 4.0 He helium 2 |
| (1) | (2) | | Key | | | | | | | | | (13) | (14) | (15) | (16) | (17) | |
| 6.9 Li lithium 3 | 9.0 Be beryllium 4 | | relative atomic mass<br>atomic symbol<br>name<br>atomic (proton) number | | | | | | | | | 10.8 B boron 5 | 12.0 C carbon 6 | 14.0 N nitrogen 7 | 16.0 O oxygen 8 | 19.0 F fluorine 9 | 20.2 Ne neon 10 |
| 23.0 Na sodium 11 | 24.3 Mg magnesium 12 | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | 27.0 Al aluminium 13 | 28.1 Si silicon 14 | 31.0 P phosphorus 15 | 32.1 S sulfur 16 | 35.5 Cl chlorine 17 | 39.9 Ar argon 18 |
| 39.1 K potassium 19 | 40.1 Ca calcium 20 | 45.0 Sc scandium 21 | 47.9 Ti titanium 22 | 50.9 V vanadium 23 | 52.0 Cr chromium 24 | 54.9 Mn manganese 25 | 55.8 Fe iron 26 | 58.9 Co cobalt 27 | 58.7 Ni nickel 28 | 63.5 Cu copper 29 | 65.4 Zn zinc 30 | 69.7 Ga gallium 31 | 72.6 Ge germanium 32 | 74.9 As arsenic 33 | 79.0 Se selenium 34 | 79.9 Br bromine 35 | 83.8 Kr krypton 36 |
| 85.5 Rb rubidium 37 | 87.6 Sr strontium 38 | 88.9 Y yttrium 39 | 91.2 Zr zirconium 40 | 92.9 Nb niobium 41 | 95.9 Mo molybdenum 42 | [98] Tc technetium 43 | 101.1 Ru ruthenium 44 | 102.9 Rh rhodium 45 | 106.4 Pd palladium 46 | 107.9 Ag silver 47 | 112.4 Cd cadmium 48 | 114.8 In indium 49 | 118.7 Sn tin 50 | 121.8 Sb antimony 51 | 127.6 Te tellurium 52 | 126.9 I iodine 53 | 131.3 Xe xenon 54 |
| 132.9 Cs caesium 55 | 137.3 Ba barium 56 | 138.9 La* lanthanum 57 | 178.5 Hf hafnium 72 | 180.9 Ta tantalum 73 | 183.8 W tungsten 74 | 186.2 Re rhenium 75 | 190.2 Os osmium 76 | 192.2 Ir iridium 77 | 195.1 Pt platinum 78 | 197.0 Au gold 79 | 200.6 Hg mercury 80 | 204.4 Tl thallium 81 | 207.2 Pb lead 82 | 209.0 Bi bismuth 83 | [209] Po polonium 84 | [210] At astatine 85 | [222] Rn radon 86 |
| [223] Fr francium 87 | [226] Ra radium 88 | [227] Ac* actinium 89 | [261] Rf rutherfordium 104 | [262] Db dubnium 105 | [266] Sg seaborgium 106 | [264] Bh bohrium 107 | [277] Hs hassium 108 | [268] Mt meitnerium 109 | [271] Ds darmstadtium 110 | [272] Rg roentgenium 111 | | | | | | | |

Elements with atomic numbers 112-116 have been reported but not fully authenticated

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 140 Ce cerium 58 | 141 Pr praseodymium 59 | 144 Nd neodymium 60 | [147] Pm promethium 61 | 150 Sm samarium 62 | 152 Eu europium 63 | 157 Gd gadolinium 64 | 159 Tb terbium 65 | 163 Dy dysprosium 66 | 165 Ho holmium 67 | 167 Er erbium 68 | 169 Tm thulium 69 | 173 Yb ytterbium 70 | 175 Lu lutetium 71 |
| 232 Th thorium 90 | [231] Pa protactinium 91 | 238 U uranium 92 | [237] Np neptunium 93 | [242] Pu plutonium 94 | [243] Am americium 95 | [247] Cm curium 96 | [245] Bk berkelium 97 | [251] Cf californium 98 | [254] Es einsteinium 99 | [253] Fm fermium 100 | [256] Md mendelevium 101 | [254] No nobelium 102 | [257] Lr lawrencium 103 |

* Lanthanide series

* Actinide series

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