

Surname <i>StemUp Model Solution</i>	Centre Number	Candidate Number
First name(s)		2



GCE AS/A LEVEL

2410U20-1



THURSDAY, 25 MAY 2023 – MORNING

CHEMISTRY – AS unit 2

Energy, Rate and Chemistry of Carbon Compounds

1 hour 30 minutes

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:

- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Do not use gel pen or correction fluid.

You may use pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.

Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.8**.

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
Section A 1. to 7.	10	
Section B 8.	6	
9.	6	
10.	18	
11.	10	
12.	13	
13.	17	
Total	80	

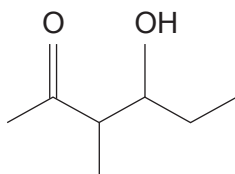
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SECTION AAnswer **all** questions.

1. Give the molecular formula of the compound shown. [1]



Molecular formula $C_7H_{14}O_2$

2. When fuels are burned with insufficient oxygen, incomplete combustion occurs and carbon monoxide is formed instead of carbon dioxide.

Write the equation for the incomplete combustion of propane, C_3H_8 . Assume that carbon monoxide is the only carbon-containing product. [1]

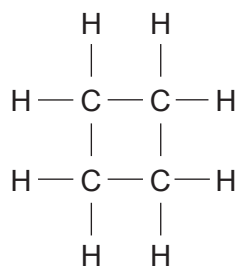


3. Name the reagent that is needed to change unsaturated oils into saturated fats. [1]

hydrogen (H_2), with a nickel catalyst

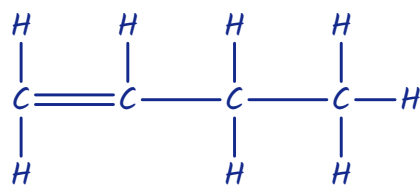


4. Cyclobutane is a cyclic hydrocarbon whose structure is shown.

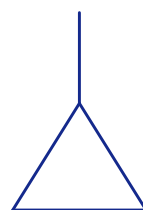


Draw the structures of **two** structural isomers of this compound.

[2]

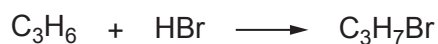


but-1-ene



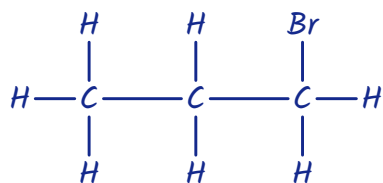
methylcyclopropane

5. Propene reacts with hydrogen bromide.

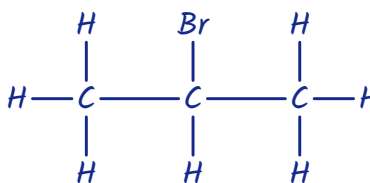


Draw the structures of the **two** isomers formed and give the name of the major product.

[2]



1-bromopropane



2-bromopropane

Major product 2-bromopropane



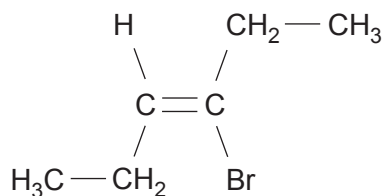
6. In the forward direction, the enthalpy change of reaction, ΔH , for a reversible endothermic reaction, has the numerical value of 60 kJ mol^{-1} .

If the activation energy, E_a , of the forward reaction is 100 kJ mol^{-1} , calculate the activation energy of the backward reaction. [1]

$$100 - 60 = 40$$

$$E_a = \dots\dots\dots 40 \dots\dots\dots \text{ kJ mol}^{-1}$$

7. Name the following *E-Z* isomer. [2]



Z-3-bromohex-3-ene



SECTION BAnswer **all** questions.

8. The use of biofuels has been proposed as the way to ensure the sustainability of energy production in the future.

Discuss the extent to which you agree with this proposal, giving both advantages and disadvantages of the use of biofuels. Include relevant examples in your answer. [6 QER]

Biofuels are made from recently living material, e.g. bioethanol from fermenting sugar cane, biodiesel from sunflower oil, and wood from trees grown and harvested for burning.

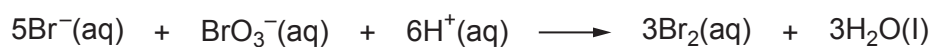
Advantages: they are renewable as crops can be regrown, unlike finite fossil fuels. The CO₂ released on burning was absorbed by photosynthesis as the plants grew, so they have a lower carbon footprint than fossil fuels, but are not fully carbon neutral as fossil fuel energy is used to farm, process and transport them. Some can be made from waste. They reduce our dependence on fossil fuels and preserve crude oil for making polymers and medicines.

Disadvantages: the land used for fuel crops is not available for other uses, so fewer food crops are grown and food prices can rise. Crops can fail due to drought or disease. Clearing land can cause deforestation and loss of habitats. Growing crops uses a lot of water, straining local resources, and large amounts of fertiliser can cause water pollution. Combustion is less efficient.

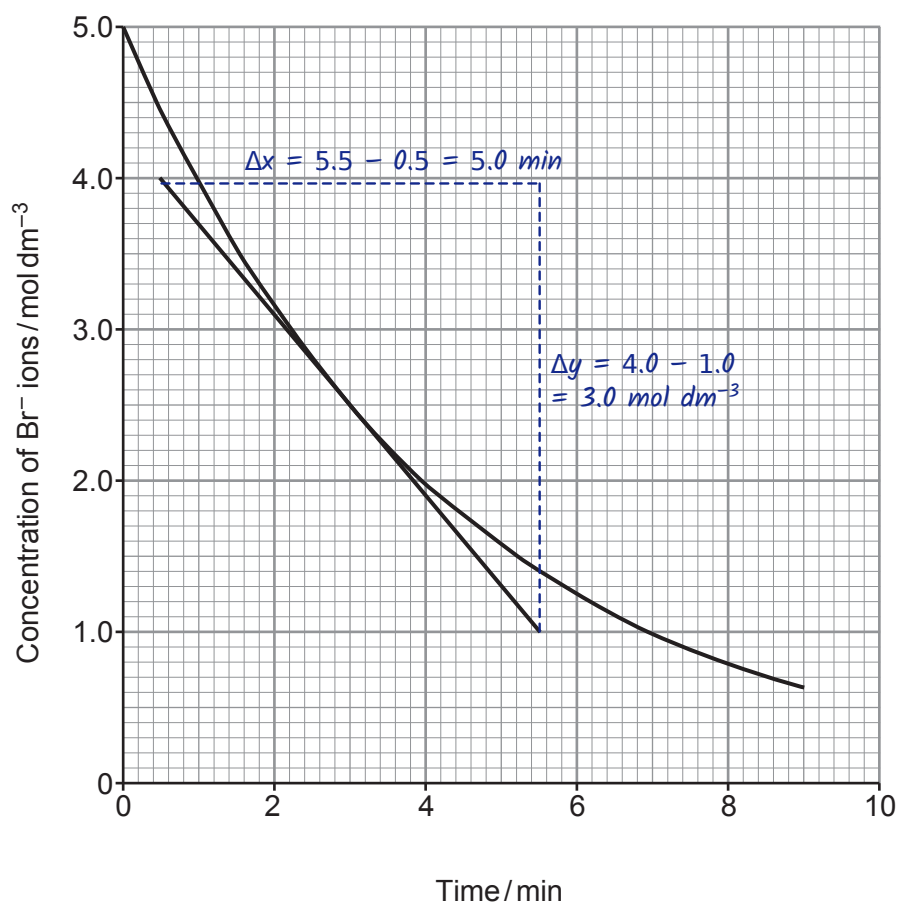
Conclusion: I partly agree. Biofuels such as bioethanol can help make energy production more sustainable, but cannot fully replace fossil fuels without harming food supply and the environment, so should be used alongside wind and solar power.



9. Bromide ions react with bromate(V) ions, BrO_3^- , as shown in the equation.



Some students investigated the rate of this reaction by following the concentration of bromide ions over time. They plotted their results as shown.



- (a) (i) The students calculated that the initial rate of the reaction was $1.20 \text{ mol dm}^{-3} \text{ min}^{-1}$.

Use the tangent to the curve to calculate the rate of the reaction when the concentration of bromide ions had fallen to 2.50 mol dm^{-3} .

You **must** show your working.

[2]

$$\begin{aligned} \text{gradient of tangent} &= \Delta y \div \Delta x = (4.0 - 1.0) \div (5.5 - 0.5) \\ &= 3.0 \div 5.0 = 0.60 \text{ (rate is the magnitude of the gradient)} \end{aligned}$$

$$\text{Rate} = \dots\dots\dots 0.60 \dots\dots\dots \text{mol dm}^{-3} \text{ min}^{-1}$$

- (ii) Use your answer to part (i) to suggest the relationship between the rate of this reaction and the concentration of bromide ions.

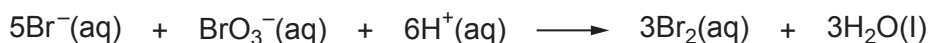
[1]

At 2.50 mol dm^{-3} (half of 5.0) the rate is 0.60 , half of 1.20 ; rate is (directly) proportional to $[\text{Br}^-]$.

- (b) Suggest how the students could follow the rate of this reaction. Explain your answer. [2]

Use a colorimeter to measure the change in colour (absorbance) with time; the solution becomes darker (more orange) as bromine is formed.

- (c) In the experiment, the concentration of bromide ions fell from 5.0 mol dm^{-3} to 2.0 mol dm^{-3} over the first 4 minutes. The initial concentration of bromate(V) ions was 1.0 mol dm^{-3} .



Using the equation, deduce the concentration of bromate(V) ions after 4 minutes.

[1]

$$\text{Br}^- \text{ used} = 5.0 - 2.0 = 3.0 \text{ mol dm}^{-3}$$

$$\text{BrO}_3^- \text{ used} = 3.0 \div 5 = 0.6 \text{ mol dm}^{-3}$$

$$\text{BrO}_3^- \text{ left} = 1.0 - 0.6 = 0.4 \text{ mol dm}^{-3}$$

$$\text{Concentration of bromate(V) ions} = \dots\dots\dots 0.4 \dots\dots\dots \text{mol dm}^{-3}$$



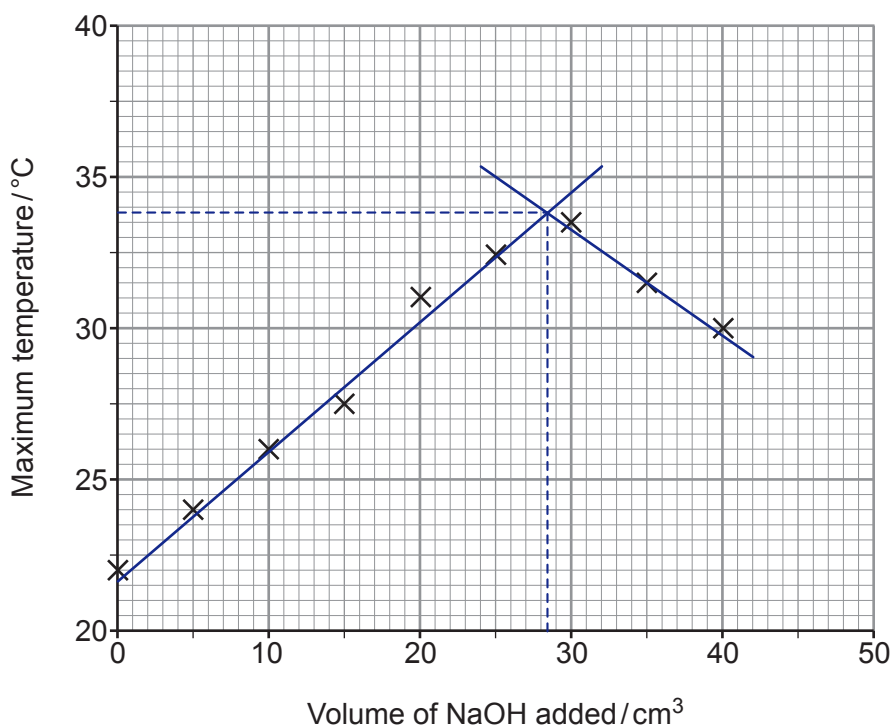
10. (a) The enthalpy of neutralisation of an acid is defined as the enthalpy change when 1 mol of aqueous H^+ ions is neutralised by aqueous OH^- ions according to the equation shown. The reaction is exothermic.



Some students followed the instructions below to determine the enthalpy change of neutralisation of methanoic acid, HCOOH .

1. Weigh 24.7 g of methanoic acid and mix with water to make 250 cm^3 of solution. Record the temperature of the solution.
2. Transfer eight 25.0 cm^3 portions of this solution into eight insulated cups.
3. Using a burette add 5.0 cm^3 of aqueous sodium hydroxide to the solution in the first cup. Stir and record the maximum temperature reached.
4. Add the following volumes of aqueous sodium hydroxide to each of the remaining cups in turn:
 10.0 cm^3 15.0 cm^3 20.0 cm^3 25.0 cm^3 30.0 cm^3 35.0 cm^3 40.0 cm^3
 Stir and record the maximum temperature reached in each cup.
5. Plot a graph of maximum temperature reached against volume of sodium hydroxide added.

Their results are plotted in the graph.



- (i) Name the apparatus used to transfer exactly 25.0 cm^3 of methanoic acid solution into the insulated cups. [1]

(25.0 cm³) pipette

- (ii) State why a higher maximum temperature is recorded when increasing volumes of sodium hydroxide are added. [1]

More H⁺ (methanoic acid) is neutralised, so more heat energy is released.

- (iii) Explain why the maximum temperature recorded decreases when more than 30 cm^3 of sodium hydroxide is added. [2]

All the H⁺ (methanoic acid) has already been neutralised, so no more heat is released; the excess (cooler) OH⁻ solution added cools the mixture, as the same energy has to heat a greater volume.

- (iv) On the graph, draw **one** straight line through the points that show an increase in maximum temperature and **another** straight line through the points that show a decrease in maximum temperature. [1]

- (v) From the graph, deduce the volume of sodium hydroxide needed to neutralise 25.0 cm^3 of the methanoic acid solution and the temperature increase at that point.

Assume that the initial temperature of every 25.0 cm^3 of methanoic acid solution is 22.0°C . [2]

Volume = *28.4* cm^3

Temperature increase = *34.0 - 22.0 = 12.0* $^\circ\text{C}$



- (vi) Use your answers to part (v) to calculate the amount of heat released by the neutralisation reaction. [2]

$$\text{total volume heated} = 25.0 + 28.4 = 53.4 \text{ cm}^3, \text{ so mass} = 53.4 \text{ g}$$

$$q = mc\Delta T = 53.4 \times 4.18 \times 12.0$$

$$q = 2679 \text{ J} = 2680 \text{ J (3 sig figs)}$$

$$\text{Heat released} = \dots\dots\dots 2680 \dots\dots\dots \text{ J}$$

- (vii) Calculate the number of moles of methanoic acid in 25.0 cm^3 of the solution and hence the enthalpy change of neutralisation of methanoic acid. [3]

$$M_r(\text{HCOOH}) = 46.02$$

$$\text{moles in } 250 \text{ cm}^3 = 24.7 \div 46.02 = 0.537 \text{ mol}$$

$$\text{moles in } 25.0 \text{ cm}^3 = 0.537 \div 10 = 0.0537 \text{ mol}$$

$$\Delta H = -q \div n = -2680 \div (0.0537 \times 1000)$$

$$\Delta H = -49.9 \text{ kJ mol}^{-1} \text{ (exothermic, so negative)}$$

$$\text{Enthalpy change of neutralisation} = \dots\dots\dots -49.9 \dots\dots\dots \text{ kJ mol}^{-1}$$



- (b) The experiment is repeated using hydrochloric acid instead of methanoic acid and a more negative value of the enthalpy change of neutralisation is calculated.

Suggest and explain a reason for this difference.

[2]

Hydrochloric acid is a strong acid (fully dissociated) and methanoic acid is a weak acid (only partially dissociated), so with HCl more H^+ is available (a higher concentration of H^+) to be neutralised.

- (c) (i) Write the equation for the reaction that occurs when solid copper(II) carbonate is added to aqueous methanoic acid to form aqueous copper(II) methanoate, $(HCOO)_2Cu$.

Include state symbols.

[2]



- (ii) State what is observed during the reaction in part (i).

[2]

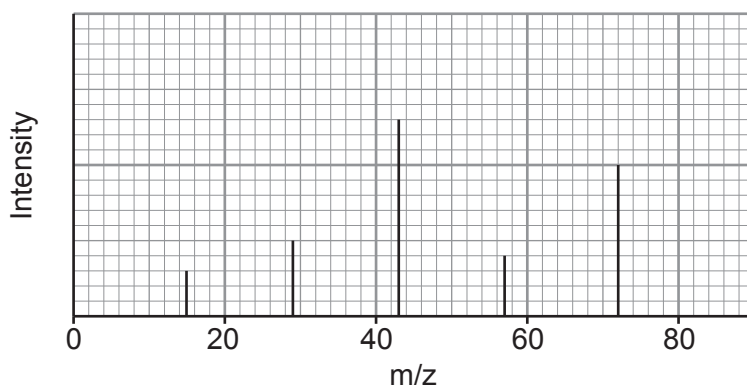
Effervescence (bubbles of gas); the green solid disappears and a blue solution forms.



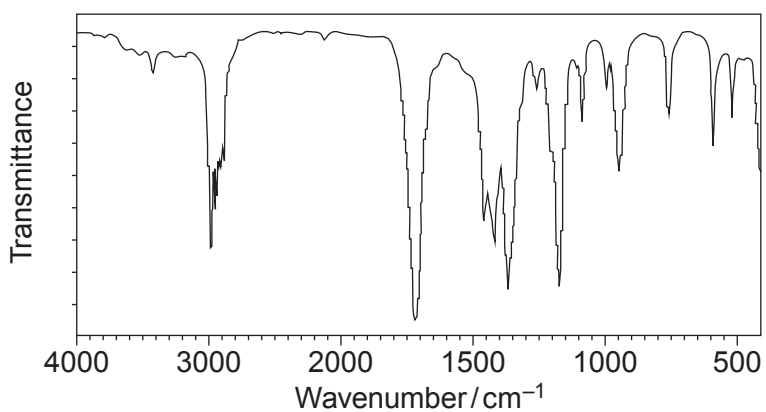
11. (a) Compound **X** contains carbon, hydrogen and oxygen only. It has no reaction with acidified potassium dichromate.

Simplified versions of its mass spectrum, IR spectrum and ^{13}C NMR spectrum are shown.

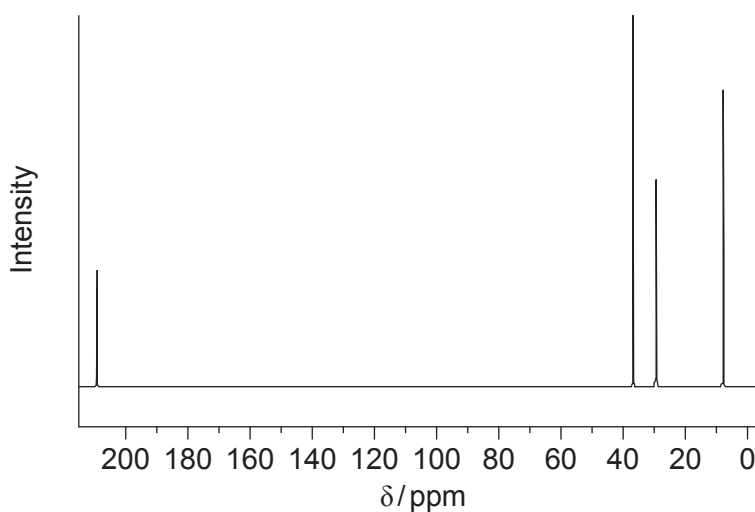
Mass spectrum



IR spectrum



^{13}C NMR spectrum



Identify compound **X**.

You **must** use information from **all** the sources given and explain how you used it. [8]

No reaction with acidified dichromate, so X is not a primary or secondary alcohol or an aldehyde; it could be a tertiary alcohol, a ketone or a carboxylic acid.

Mass spectrum: the molecular ion peak is at m/z 72, so $M_r = 72$. Fragments: m/z 15 = CH_3^+ , 29 = C_2H_5^+ , 43 = $\text{CH}_3\text{C}=\text{O}^+$ and 57 = $\text{C}_2\text{H}_5\text{C}=\text{O}^+$.

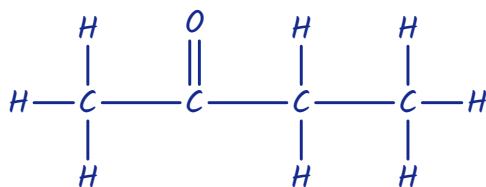
IR: the strong peak at about 1720 to 1750 cm^{-1} shows $\text{C}=\text{O}$ is present. There is no broad $\text{O}-\text{H}$ peak, so X is not a carboxylic acid (or an alcohol).

^{13}C NMR: four peaks, so there are four different carbon environments. The peak at about 210 ppm shows the $\text{C}=\text{O}$ carbon of an aldehyde or ketone; the peaks at about 30 to 40 ppm are carbons next to the $\text{C}=\text{O}$, so it must be a ketone; the peak at about 8 ppm is a CH_3 carbon.

Ketone $\text{C}=\text{O}$ (28) leaves $72 - 28 = 44 = \text{C}_3\text{H}_8$, so the molecular formula is $\text{C}_4\text{H}_8\text{O}$.

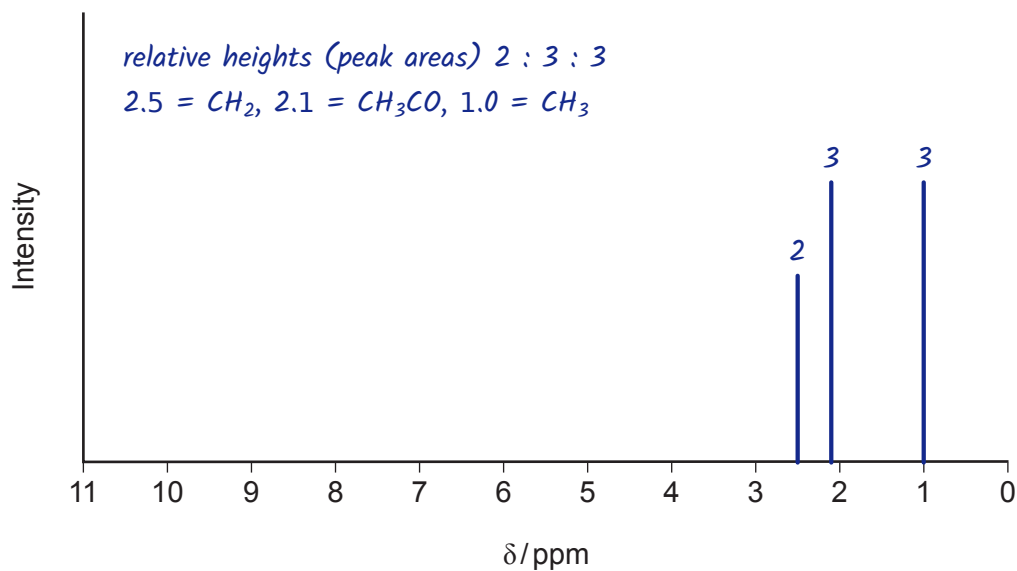
X is butanone, $\text{CH}_3\text{COCH}_2\text{CH}_3$; a ketone with four carbon environments, giving CH_3CO^+ (43) and $\text{C}_2\text{H}_5\text{CO}^+$ (57).

Compound **X** butanone, $\text{CH}_3\text{COCH}_2\text{CH}_3$



- (b) On the axes below, complete the low resolution ^1H NMR spectrum you would expect for the compound you identified in part (a).

You should indicate where you would expect to see peaks **and** the relative intensities of the peaks. [2]



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12. (a) **Y** is a halogenocompound in which each molecule contains one atom of chlorine, bromine or iodine.

- (i) Describe a chemical test to determine which halogen is present in **Y**. [3]

Warm Y with aqueous NaOH, then neutralise (acidify) with dilute HNO₃. Add aqueous silver nitrate, AgNO₃(aq).

White precipitate = chlorine, cream precipitate = bromine, yellow precipitate = iodine.

- (ii) **Y** contains four carbon atoms in each molecule. The percentage by mass of halogen present in **Y** is less than 40%.

Identify **Y**. Explain how you reached your conclusion. [2]

Y is chlorobutane, C₄H₉Cl. $M_r = 4(12.0) + 9(1.01) + 35.5 = 92.6$, so %

Cl = $35.5 \div 92.6 \times 100 = 38\%$, less than 40%.

C₄H₉Br: % Br = $79.9 \div 137.0 \times 100 = 58\%$ (and more for iodine), so Br

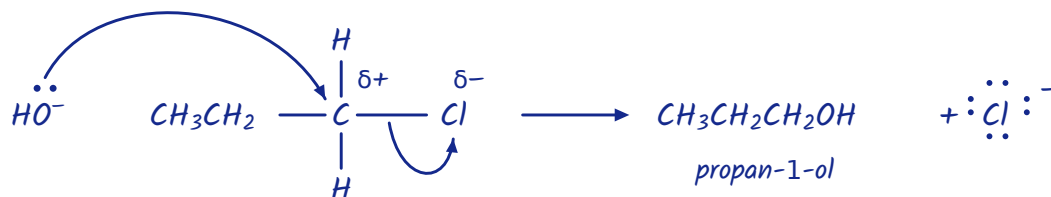
and I are greater than 40%.



- (b) (i) Halogenoalkanes react with aqueous sodium hydroxide.

Draw the mechanism to show the reaction of 1-chloropropane with aqueous sodium hydroxide.

You should include all charges, partial charges and lone pairs, and curly arrows to show electron movement. [4]



- (ii) Name the type of reaction shown in part (i). [1]

nucleophilic substitution (hydrolysis)

- (c) Halogenoalkanes can also take part in an elimination reaction.

2-Chloropentane undergoes elimination in a similar way to 1-chloropropane.

- (i) Give the reagent and conditions needed for 2-chloropentane to undergo elimination. [1]

Heat under reflux with ethanolic (alcoholic) sodium hydroxide.

- (ii) When 2-chloropentane undergoes elimination, two structural isomers are formed.

Give the structures of these **two** isomers. [2]

$\text{CH}_2=\text{CHCH}_2\text{CH}_2\text{CH}_3$ (pent-1-ene)

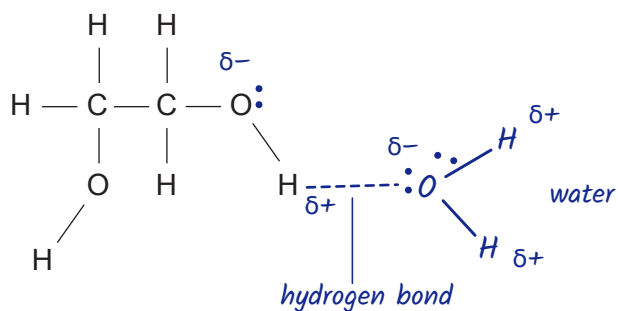
$\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_3$ (pent-2-ene)



13. (a) In cold weather the wings of an aeroplane can become covered in ice. For safety reasons the wings must be de-iced.

The liquid ethane-1,2-diol, $\text{CH}_2\text{OHCH}_2\text{OH}$, is used, mixed with water, since this lowers the freezing temperature of water and causes the ice to melt.

- (i) Use the diagram below to show the intermolecular forces that allow ethane-1,2-diol to dissolve in water. [3]



- (ii) Suggest a reason why the addition of ethane-1,2-diol lowers the freezing temperature of water. [1]

The diol disrupts the hydrogen bonding between water molecules, so this stops the ice lattice from forming.



(b) Ethane-1,2-diol can be oxidised to ethanedioic acid, $(\text{COOH})_2$.

(i) Suggest an oxidising agent suitable to carry out this reaction. [1]

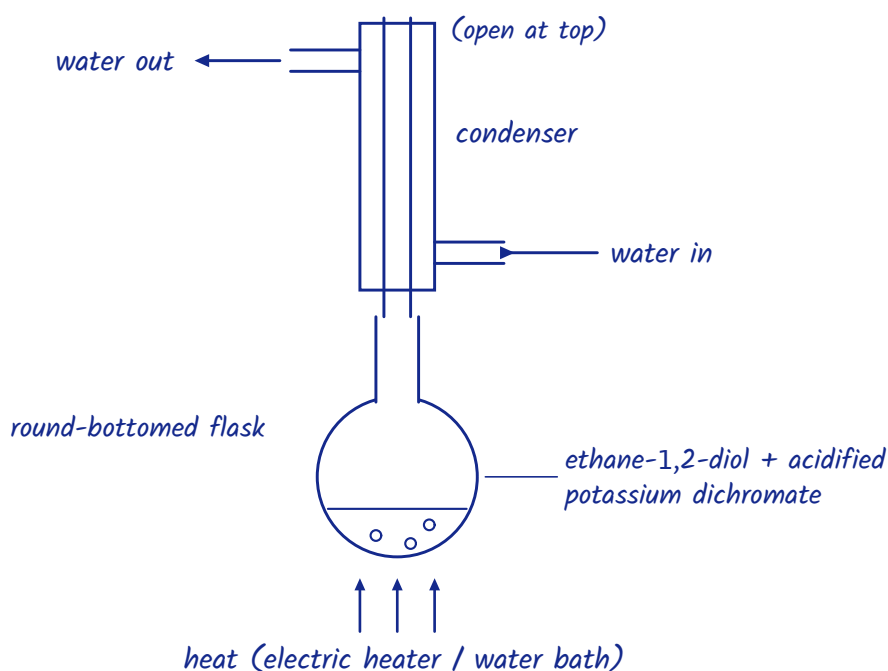
acidified potassium dichromate(VI), $\text{K}_2\text{Cr}_2\text{O}_7 / \text{H}_2\text{SO}_4$

(ii) Write the equation for this reaction. Use [O] for the oxidising agent. [2]

$\text{CH}_2\text{OHCH}_2\text{OH} + 4[\text{O}] \rightarrow (\text{COOH})_2 + 2\text{H}_2\text{O}$

(iii) To ensure complete oxidation the reagents are refluxed.

Draw and label the apparatus as it is being used in this reaction. [2]



(iv) A sample of the reacting mixture was taken during the reflux process and a mass spectrum was produced. One of the peaks recorded was at m/z 58.

Suggest the identity of the **molecular ion** that gave this peak. [1]

$[(\text{HCO})_2]^+$, i.e. ethanedial ion $\text{OHC}-\text{CHO}^+$



- (v) The reaction can be used to prepare a sample of solid ethanedioic acid. This is generally hydrated as $(\text{COOH})_2 \cdot x\text{H}_2\text{O}$ where x is an integer.

2.00 g of ethane-1,2-diol was oxidised and 3.94 g of hydrated ethanedioic acid was produced.

Calculate the relative molecular mass of hydrated ethanedioic acid and hence the value of x in its formula. [4]

$$n(\text{ethane-1,2-diol}) = 2.00 \div 62.06 = 0.0322 \text{ mol}$$

$$1 : 1 \text{ ratio, so } n(\text{hydrated ethanedioic acid}) = 0.0322 \text{ mol}$$

$$M_r \text{ of } (\text{COOH})_2 \cdot x\text{H}_2\text{O} = 3.94 \div 0.0322 = 122$$

$$M_r \text{ of } (\text{COOH})_2 = 90.0, \text{ so mass of water} = 122 - 90 = 32$$

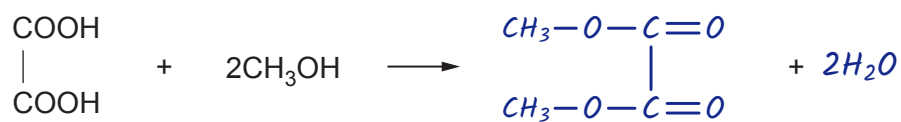
$$x = 32 \div 18.0 = 1.8, \text{ so } x = 2 \text{ (nearest integer)}$$

$$x = \dots\dots\dots 2 \dots\dots\dots$$



- (vi) I. Complete the equation for the reaction which occurs when ethanedioic acid is heated with excess methanol in acidic conditions.

Clearly show the structure of the organic product. [2]



- II. Name the type of functional group present in the organic product. [1]

ester

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