Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

0256416902

CHEMISTRY **9701/21**

Paper 2 AS Level Structured Questions **October/November 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **11** printed pages and **1** blank page.

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[Turn over

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

1 **(a)** Chlorine can be prepared using the following reaction.

$$MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

(i) Explain why $MnO_2(s)$ is described as an oxidising agent in this reaction.

Refer to oxidation numbers in your answer.

.....

..... [1]

(ii) State what you would observe during this reaction.

..... [1]

(b) The halogens chlorine, bromine and iodine are all volatile elements.

State and explain the trend in volatility down Group 17.

.....

.....

..... [3]

(c) Chlorine undergoes disproportionation during many chemical reactions.

(i) Write an equation for the reaction of chlorine with cold aqueous sodium hydroxide, NaOH.

Explain why it is a disproportionation reaction.

equation .....

explanation .....

.....
[2]

(ii) One of the products of the reaction of chlorine with **hot** aqueous sodium hydroxide differs from those in **(c)(i)**.

Identify the compound that is formed in this reaction that is different from that formed in the reaction in **(c)(i)**.

..... [1]

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(d) State and explain the use of chlorine in water purification.

.....

.....

..... [2]

(e) Under certain conditions, chlorine undergoes a free-radical substitution reaction with ethane.

(i) State the conditions required to initiate this reaction.

..... [1]

(ii) Write the overall equation for this free-radical substitution reaction.

..... [1]

[Total: 12]

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[Turn over

2 **(a)** Complete the table to give details of the type of bonding and structure shown by some of the oxides of Period 3 elements.

	Na_2O	MgO	Al_2O_3	SiO_2	SO_3
boiling point / °C	1275	3670	2977	2950	45
nature of oxide	basic	basic	amphoteric	acidic	acidic
bonding					
structure					

[2]

(b) **(i)** Explain why the boiling point of SiO_2 is much higher than the boiling point of SO_3.

.....

.....

.....

..... [3]

(ii) Al_2O_3 is an amphoteric oxide.

Explain what is meant by the term *amphoteric*. Use chemical equations to illustrate your answer.

.....

.....

..... [3]

(iii) State what you would observe when a small sample of Na_2O is placed in water.

..... [1]

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(c) Selenium is a Group 16 element which shows similar chemical reactions to sulfur.

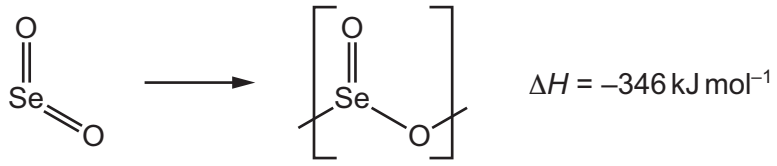
(i) Selenium reacts with fluorine to form SeF_6 molecules.

Predict the shape of a molecule of SeF_6.

..... [1]

(ii) The most stable oxide of selenium is SeO_2.

Gaseous SeO_2 reacts to form a solid polymer, as shown. In the reaction one Se=O is replaced by two Se–O to form a polymer.



$\Delta H = -346\,kJ\,mol^{-1}$

The bond enthalpy of Se=O is $514\,kJ\,mol^{-1}$.

Use these data to calculate the bond enthalpy, in $kJ\,mol^{-1}$, of Se–O.

bond enthalpy of Se–O = ... $kJ\,mol^{-1}$
[2]

(iii) SeO_2 shows similar chemical reactions to SO_2.

Suggest an equation to show the reaction of SeO_2 with aqueous sodium hydroxide, NaOH.

..... [1]

[Total: 13]

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[Turn over

3 Crude oil is a natural source of hydrocarbons that are used as fuels.

(a) Hydrocarbons with low relative molecular mass, M_r, are used as fuels in industry, in the home and for transport.

There is a high demand for the hydrocarbons with low M_r.

(i) Name the process by which long-chain hydrocarbons are broken down into shorter-chain hydrocarbons.

..... [1]

(ii) Give one reason why hydrocarbons with low M_r are suitable for use as fuels.

..... [1]

(iii) Incomplete combustion of hydrocarbons can release carbon monoxide, CO, into the atmosphere.

Write an equation for the formation of CO from the incomplete combustion of butene, C_4H_8.

..... [1]

(iv) Identify an analytical technique that can be used to monitor the levels of CO in the atmosphere.

Outline how this analytical technique may be used to monitor the levels of CO.

.....

.....

..... [2]

(b) Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

(i) Construct the equation for the complete combustion of thiophene, $C_4H_4S(l)$.

Include state symbols in your answer.

..... [2]

(ii) A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

Explain the meaning of the term *enthalpy change of combustion*.

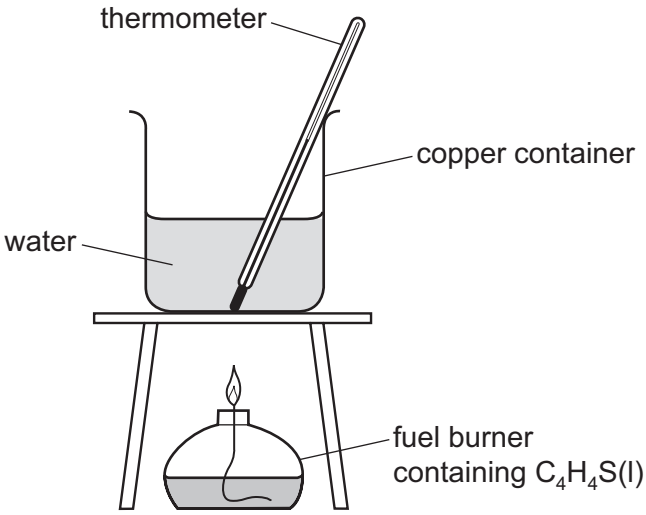
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.....

..... [2]

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(iii) The student uses the following apparatus in the experiment.



mass of water in copper container / g	200
initial temperature of water / °C	18.5
highest temperature of water / °C	37.5

Calculate the heat energy released, in J, by the reaction.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of water by 1.0 °C.

Assume no heat is lost to the surroundings.

heat energy released = ... J
[2]

(iv) The student used 0.63 g of $C_4H_4S(l)$ in the experiment.

Calculate the enthalpy change of combustion of thiophene, $\Delta H_c(C_4H_4S(l))$. Include a sign in your answer.

$\Delta H_c(C_4H_4S(l))$ = ... $kJ\,mol^{-1}$
[2]

[Total: 13]

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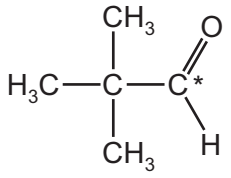
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4 $(CH_3)_3CCHO$ is used in the synthesis of some antibiotics.

(a) (i) Give the name of $(CH_3)_3CCHO$.

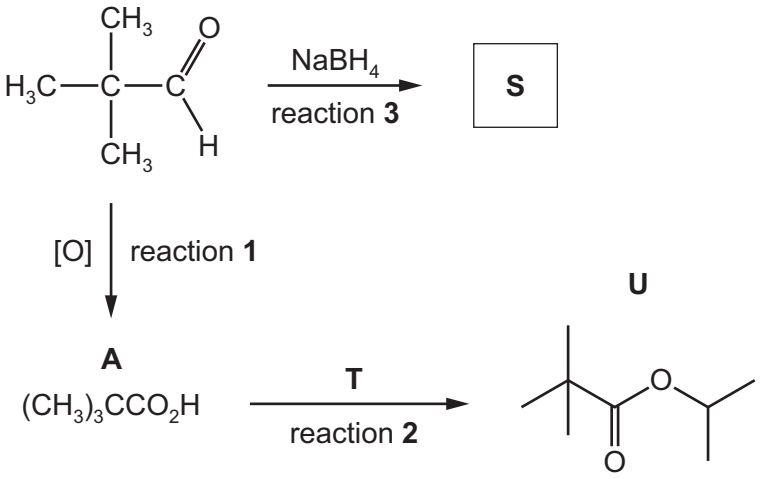
..... [1]

(ii) State the hybridisation of the carbon atom labelled with an asterisk, *.



..... [1]

(b) Two reaction sequences are shown.



(i) Reaction **1** is an oxidation reaction.

Identify the reagent(s) and conditions for reaction **1**.

..... [1]

(ii) **A**, $(CH_3)_3CCO_2H$, is a solid at room temperature.

B, $CH_3CO_2(CH_2)_2CH_3$, is an isomer of **A**. **B** is a liquid at room temperature.

Explain the difference in the physical states of **A** and **B**, with reference to any intermolecular forces that may exist.

.....

.....

.....

..... [3]

(iii) Give the balanced equation for the reaction of $(CH_3)_3CCHO$ with $NaBH_4$ to form **S**.

Use [H] to represent an atom of hydrogen provided by $NaBH_4$.

..... [1]

(iv) Draw the structure of the organic molecule **T** that reacts with **A**, $(CH_3)_3CCO_2H$, in reaction **2**, to form **U**.

Suggest a catalyst for reaction **2**.

T

catalyst .....
[2]

(c) **X**, **Y** and **Z** are all isomers of $(CH_3)_3CCHO$.

A summary of some of the reactions and properties of **X**, **Y** and **Z** is shown in the table.

compound	observations with 2,4-DNPH	observations with Fehling's solution	principal absorptions in infra-red spectrum
X		no reaction	1715 cm^{-1}
Y		red precipitate	1730 cm^{-1}
Z	no reaction	no reaction	3200–3600 cm^{-1} 1630 cm^{-1} 1050 cm^{-1}

(i) **X** and **Y** each contains a carbonyl group.

Complete the table with the expected observations for the reactions of **X** and **Y** with 2,4-DNPH. [1]

(ii) Identify the functional group present in **Y** that causes the recorded observation with Fehling's solution.

..... [1]

(iii) **Y** has a chiral centre and exists as a pair of optical isomers.

State what is meant by the term *chiral centre*.

.....

..... [1]

(iv) Draw the optical isomers of **Y** using the conventional three-dimensional representation.

[2]

Z, $C_5H_{10}O$, has a branched carbon chain. It shows geometrical isomerism.

(v) Complete the table with the bond responsible for each of the principal absorptions seen in the infra-red spectrum of **Z**.

principal absorptions in infra-red spectrum	bond responsible
3200–3600 cm^{-1}	
1630 cm^{-1}	
1050 cm^{-1}	

[1]

(vi) Draw the skeletal formula of **Z**.

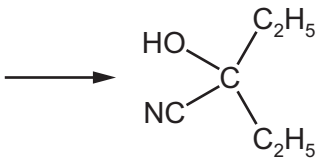
[3]

(vii) **X** contains a carbonyl group. **X** reacts with HCN, in the presence of a small amount of NaCN, to form $(C_2H_5)_2C(OH)CN$ as shown.

$$\mathbf{X} + HCN \rightarrow (C_2H_5)_2C(OH)CN$$

Draw the mechanism of the reaction of **X** with HCN.

- Draw the structure of **X** and the intermediate.
- Include all charges, partial charges, lone pairs and curly arrows.



[3]

(viii) State the role of NaCN in the reaction in **(c)(vii)**.

..... [1]

[Total: 22]

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