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9701/21

October/November 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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You may use an HB pencil for any diagrams or graphs.

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DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

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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.

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

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



- (i) Explain why $\text{MnO}_2(\text{s})$ 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]

(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]

- 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 ₂ O	MgO	Al ₂ O 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 SiO₂ is much higher than the boiling point of SO₃.

.....

.....

.....

..... [3]

- (ii) Al₂O₃ 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 Na₂O is placed in water.

..... [1]

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

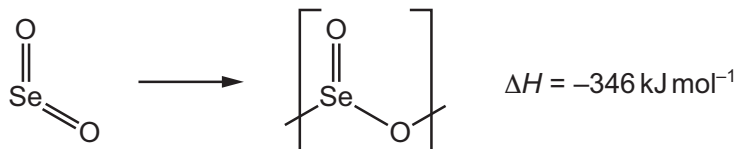
(i) Selenium reacts with fluorine to form SeF_6 molecules.

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 $\text{Se}=\text{O}$ is replaced by two $\text{Se}-\text{O}$ to form a polymer.



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

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

bond enthalpy of $\text{Se}-\text{O}$ = ... 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]

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]

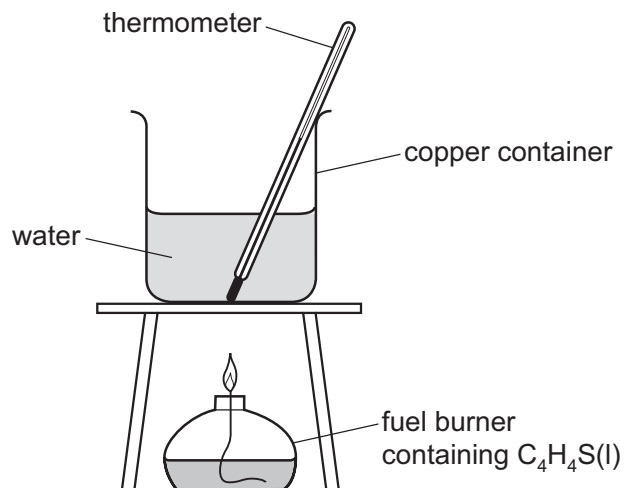
- (ii) A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

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

.....

 [2]

- (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 cm³ 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.

$\Delta H_c(C_4H_4S(l)) = \dots\dots\dots$ kJ mol⁻¹
[2]

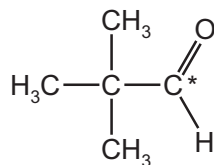
[Total: 13]

4 $(\text{CH}_3)_3\text{CCHO}$ is used in the synthesis of some antibiotics.

(a) (i) Give the name of $(\text{CH}_3)_3\text{CCHO}$.

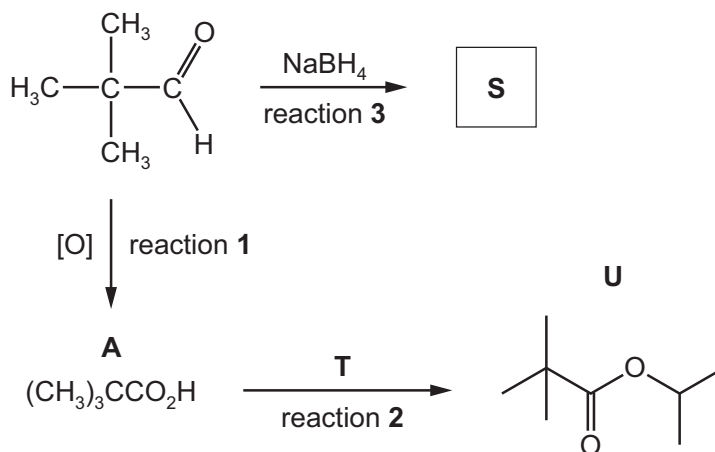
..... [1]

(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**, $(\text{CH}_3)_3\text{CCO}_2\text{H}$, is a solid at room temperature.

B, $\text{CH}_3\text{CO}_2(\text{CH}_2)_2\text{CH}_3$, 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]

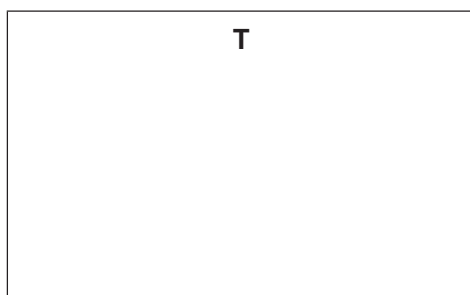
(iii) Give the balanced equation for the reaction of $(\text{CH}_3)_3\text{CCHO}$ with NaBH_4 to form **S**.

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**, $(\text{CH}_3)_3\text{CCO}_2\text{H}$, in reaction 2, to form **U**.

Suggest a catalyst for reaction 2.



catalyst [2]

(c) **X**, **Y** and **Z** are all isomers of $(\text{CH}_3)_3\text{CCHO}$.

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	$3200\text{--}3600\text{ cm}^{-1}$ 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**.

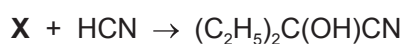
principal absorptions in infra-red spectrum	bond responsible
3200–3600 cm^{-1}	
1630 cm^{-1}	
1050 cm^{-1}	

[1]

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

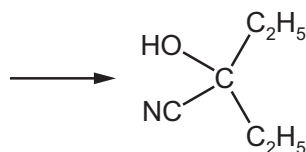
[3]

- (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.



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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CHEMISTRY

9701/22

Paper 2 AS Level Structured Questions

October/November 2019

1 hour 15 minutes

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

- 1 In the Periodic Table, the p block contains elements whose outer electrons are found in the p subshell.
- (a) Elements in the p block show a general increase in first ionisation energy as the atomic number increases.
- (i) Draw the shape of a p orbital.

[1]

- (ii) Write an equation to show the first ionisation energy of silicon.

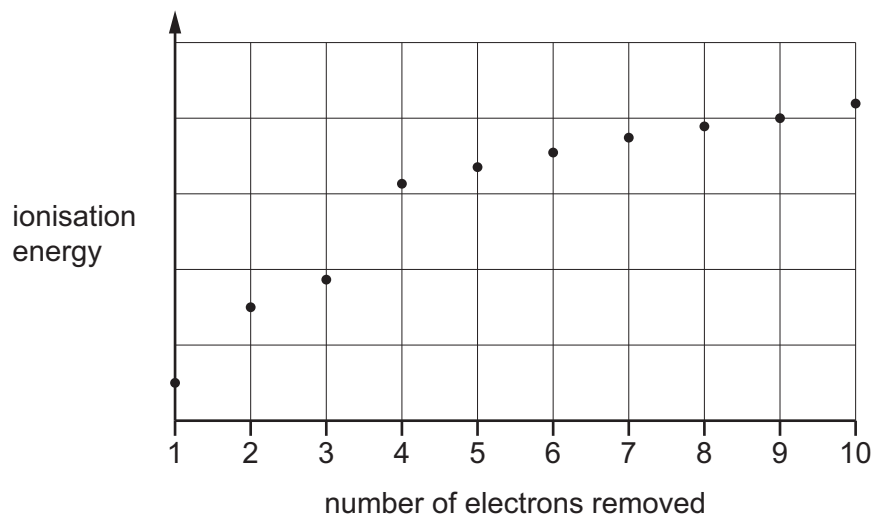
[1]

- (iii) Explain why there is a general increase in first ionisation energies of the elements across Period 3.

[2]

(iv) Element **A** is in the p block.

The graph shows the successive ionisation energies for the removal of the first ten electrons of **A**.



State and explain the group of the Periodic Table that element **A** belongs to.

group number

explanation

.....

.....

[2]

- (b) Silicon is found in many compounds in the Earth's crust. Silicon has only three naturally occurring isotopes, ^{28}Si , ^{29}Si and ^{30}Si .

- (i) The table shows data for ^{28}Si , ^{29}Si and ^{30}Si .

	^{28}Si	^{29}Si	^{30}Si
relative isotopic mass	28.0	29.0	30.0

A sample of silicon contains 92.2% ^{28}Si . The total percentage abundance of ^{29}Si and ^{30}Si in the sample is 7.8%.

The relative atomic mass, A_r , of silicon in the sample is 28.09.

Calculate the percentage abundance of ^{30}Si .

Give your answer to **one** decimal place.

percentage abundance of ^{30}Si = ... %
[3]

- (ii) Silicon reacts with nitrogen gas to form Si_3N_4 .

Si_3N_4 is a solid with a melting point of 1900 °C. It is insoluble in water and does not conduct electricity when molten.

Suggest the type of bonding in **and** structure of Si_3N_4 . Explain your answer.

.....

 [3]

- (c) Sulfur-containing compounds, such as $\text{C}_2\text{H}_5\text{SH}$, are found in fossil fuels, and produce SO_2 when they are burned.

- (i) Write the equation to show the complete combustion of $\text{C}_2\text{H}_5\text{SH}$.

..... [1]

- (ii) State why the presence of SO_2 in the atmosphere has environmental consequences. Describe **one** of the consequences on the environment.

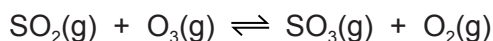
.....

.....

..... [2]

- (d) SO_2 can react with ozone, O_3 , to form SO_3 in two different reactions.

- (i) In one reaction, SO_2 reacts with O_3 until a dynamic equilibrium is established.



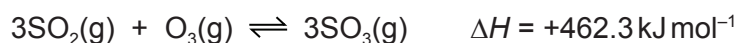
State and explain the effect of an increase in pressure on the composition of the equilibrium mixture.

.....

.....

..... [2]

- (ii) In the other reaction, a different equilibrium is established at 300 K as shown.



Suggest a temperature needed to increase the yield of SO_3 at equilibrium.

Explain your answer.

.....

.....

..... [2]

[Total: 19]

- 2 Oxygen is the most abundant element in the Earth's crust. It reacts with other elements to form stable compounds, ions and molecules.

(a) Complete the table to give the formulae and acid/base behaviour of some of the oxides of the Period 3 elements.

element	sodium	aluminium	silicon	phosphorus	sulfur
formula of oxide	Na ₂ O				SO ₃
acid/base behaviour		amphoteric			

[2]

(b) Group 2 elements form stable hydroxides, with general formula M(OH)₂, where M is the Group 2 element.

- (i) Beryllium hydroxide, Be(OH)₂, is an amphoteric compound that shows similar chemical reactions to aluminium oxide.

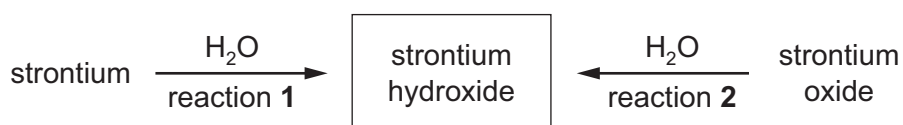
State the meaning of the term *amphoteric*.

.....
 [1]

- (ii) Write an **ionic** equation for the reaction of magnesium hydroxide, Mg(OH)₂, with hydrochloric acid.

..... [1]

- (iii) Two methods of preparing strontium hydroxide are shown.



State **one** difference between the observations you would make for reaction 1 and reaction 2.

.....

 [1]

- (iv) State how the solubility of the Group 2 hydroxides changes down the group.

..... [1]

(c) Sodium peroxide, Na_2O_2 , reacts with CO_2 .



The partial pressure of $\text{CO}_2(\text{g})$ in a 0.500 dm^3 sample of air is 5.37 kPa at 20°C .

(i) Calculate the amount, in moles, of $\text{CO}_2(\text{g})$ present in the sample of air at 20°C .

amount of $\text{CO}_2(\text{g}) = \dots\dots\dots\text{ mol}$ [2]

(ii) Calculate the mass of $\text{Na}_2\text{O}_2(\text{s})$ that would react fully with the amount of $\text{CO}_2(\text{g})$ calculated in (i).

mass of $\text{Na}_2\text{O}_2(\text{s}) = \dots\dots\dots\text{ g}$ [1]

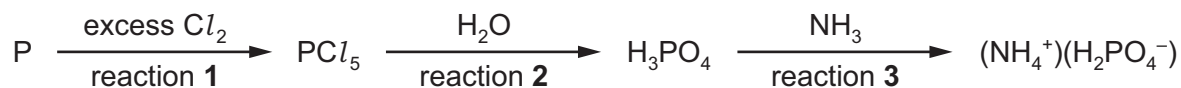
(iii) The peroxide ion, O_2^{2-} , has a single covalent bond between the two oxygen atoms. Each oxygen atom carries a negative charge.

Draw a 'dot-and-cross' diagram for the peroxide ion. Show outer electrons only.

[2]

[Total: 11]

3 A series of reactions for phosphorus and its compounds is shown.



(a) (i) State what you would observe in reaction 1.

.....
 [1]

(ii) State the type of reaction that occurs in reaction 2.

..... [1]

(iii) H_3PO_4 can be produced by direct reaction of phosphorus with nitric acid.



Use oxidation numbers to show that this reaction is a redox reaction.

.....

 [2]

(b) Reaction 3 is a neutralisation reaction in which NH_3 acts as a base.

(i) Explain how NH_3 acts as a base in reaction 3.

.....
 [1]

(ii) Draw the three-dimensional shape of the ammonium ion, NH_4^+ . Give the bond angle.

bond angle = ... ° [1]

(iii) State the industrial importance of compounds such as $(\text{NH}_4^+)(\text{H}_2\text{PO}_4^-)$.

..... [1]

(c) PCl_5 can be used to convert alcohols to halogenoalkanes.

(i) Write an equation for the reaction of $\text{C}_2\text{H}_5\text{OH}$ with PCl_5 to form $\text{C}_2\text{H}_5\text{Cl}$.

..... [1]

(ii) State the type of reaction in (i).

..... [1]

(iii) Halogenoalkanes can also be prepared by reacting alcohols with hydrogen halides, such as HCl and HI .

- HCl is prepared using NaCl and concentrated H_2SO_4 .
- HI is prepared by reacting NaI with concentrated H_3PO_4 .

Suggest why HI is **not** prepared by the reaction of NaI with concentrated H_2SO_4 .

.....

 [2]

(iv) The rate of the hydrolysis reaction of halogenoalkanes with NaOH(aq) is dependent on the halogen that is bonded to carbon.

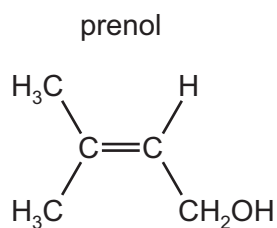
State and explain the order of reactivity when NaOH(aq) reacts separately with $\text{C}_2\text{H}_5\text{Cl}$, $\text{C}_2\text{H}_5\text{Br}$ and $\text{C}_2\text{H}_5\text{I}$.

.....

 [2]

[Total: 13]

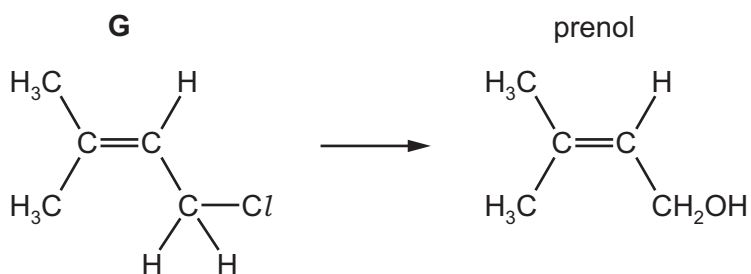
- 4 Prenol is a naturally occurring organic molecule found in many fruits. It contains both an alkene and an alcohol functional group.



- (a) Prenol can be formed by the reaction of **G** with NaOH(aq).

Complete the diagram to show the mechanism of the reaction between **G** and NaOH(aq) to form prenol.

Include all relevant charges, partial charges, lone pairs and curly arrows.



[2]

- (b) Prenol reacts with steam to form a mixture of three isomers, **J**, **K** and **L**, of molecular formula $C_5H_{12}O_2$.

- (i) When **J** is heated with excess acidified potassium dichromate(VI) it forms an organic product which shows no reaction with 2,4-DNPH.

Draw the structure of **J**.

[1]

K and **L** are stereoisomers with molecular formula $C_5H_{12}O_2$.

K and **L** both react when heated with excess acidified potassium dichromate(VI) to form **M**, $C_5H_8O_3$.

M forms an orange precipitate on reaction with 2,4-DNPH.

(ii) Give the structural formula of **K** and **L**.

..... [1]

(iii) Name the type of stereoisomerism shown by **K** and **L**.

..... [1]

(iv) Give the balanced equation to represent the reaction of **K**, $C_5H_{12}O_2$, with acidified potassium dichromate(VI) to form **M**, $C_5H_8O_3$.

Use [O] to represent an atom of oxygen provided by the oxidising agent.

..... [1]

(c) (i) Prenol contains an alkene functional group.

Describe a chemical test to confirm the presence of an alkene functional group. Give the result of the test.

.....

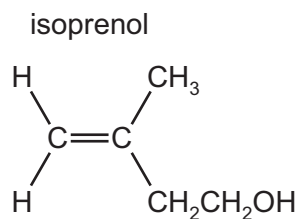
..... [1]

(ii) Prenol can be polymerised to form poly(prenol).

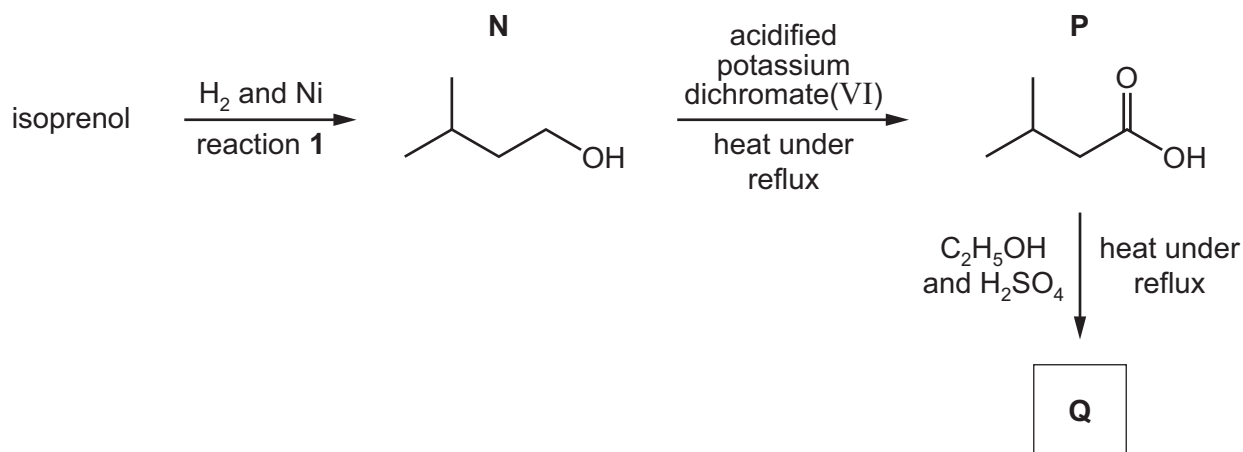
Draw **one** repeat unit of poly(prenol).

[1]

(d) Isoprenol is a structural isomer of prenol.



The series of reactions shows how isoprenol can be used to form **Q**, a sweet-smelling liquid.



(i) Give the name of **N**.

..... [1]

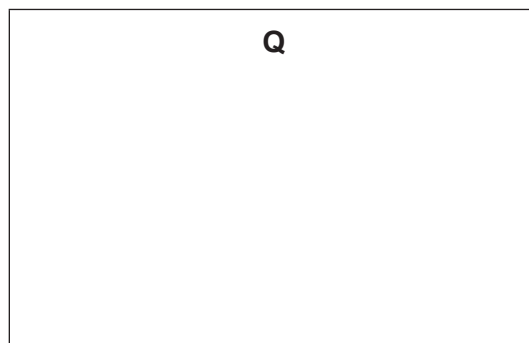
(ii) Isoprenol is a liquid.

Ni acts as a catalyst for reaction 1.

Identify the type of catalysis shown by Ni in reaction 1.

..... [1]

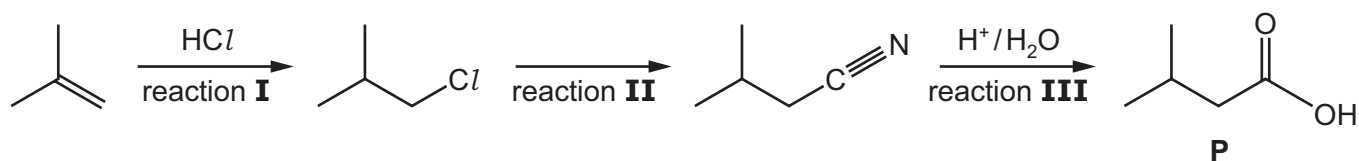
(iii) Draw the **skeletal** formula of **Q** and suggest one commercial use of **Q**.



commercial use

[2]

(e) **P** can be produced as shown.



(i) The progress of reaction **I** can be monitored using infra-red spectroscopy.

One absorption that can be used to monitor the progress of this reaction is that of C–Cl at 730 cm^{-1} .

Identify another absorption that can be used to monitor the progress of this reaction. In your answer, you should refer to the specific bond and its corresponding absorption range in wavenumbers.

.....
 [1]

(ii) State the reagent(s) needed for reaction **II**.

..... [1]

(iii) Name the type of reaction that occurs in reaction **III**.

..... [1]

(iv) The yield of reaction **I** is very low.

Explain why.

.....

 [2]

[Total: 17]

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

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

State and explain the trend in volatility down Group 17.

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- (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]

(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]

- 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 ₂ O	MgO	Al ₂ O 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 SiO₂ is much higher than the boiling point of SO₃.

.....

 [3]

- (ii) Al₂O₃ 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 Na₂O is placed in water.

..... [1]

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

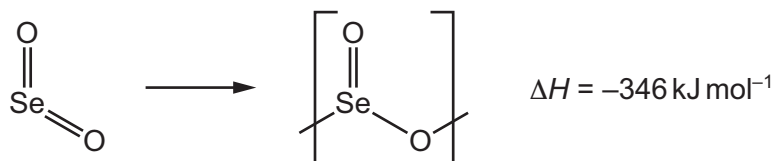
- (i) Selenium reacts with fluorine to form SeF_6 molecules.

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 $\text{Se}=\text{O}$ is replaced by two $\text{Se}-\text{O}$ to form a polymer.



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

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

bond enthalpy of $\text{Se}-\text{O} = \dots\dots\dots \text{kJ mol}^{-1}$
[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]

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]

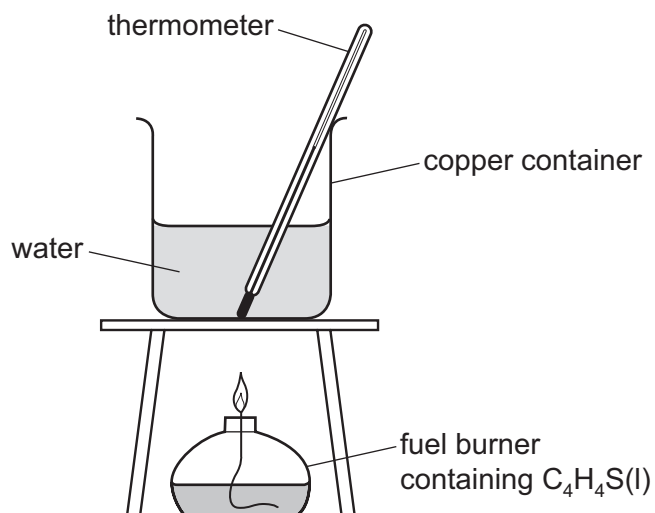
- (ii)** A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

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

.....

 [2]

- (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 cm³ 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.

$\Delta H_c(C_4H_4S(l)) = \dots\dots\dots$ kJ mol⁻¹
[2]

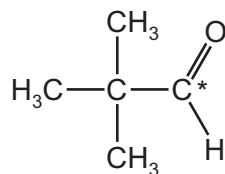
[Total: 13]

4 $(\text{CH}_3)_3\text{CCHO}$ is used in the synthesis of some antibiotics.

(a) (i) Give the name of $(\text{CH}_3)_3\text{CCHO}$.

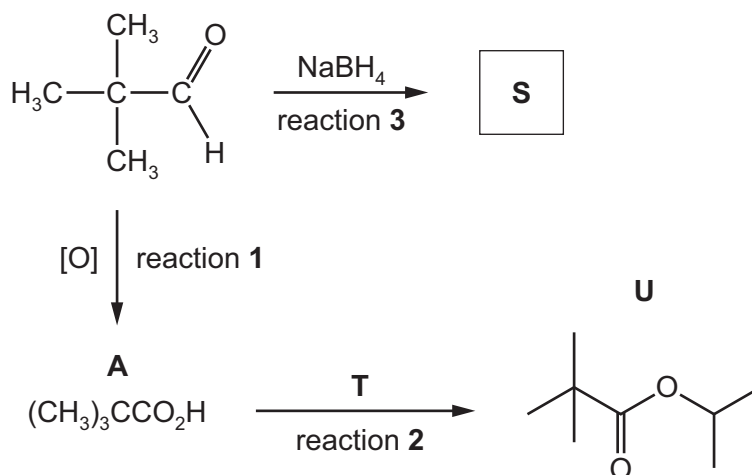
..... [1]

(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**, $(\text{CH}_3)_3\text{CCO}_2\text{H}$, is a solid at room temperature.

B, $\text{CH}_3\text{CO}_2(\text{CH}_2)_2\text{CH}_3$, 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]

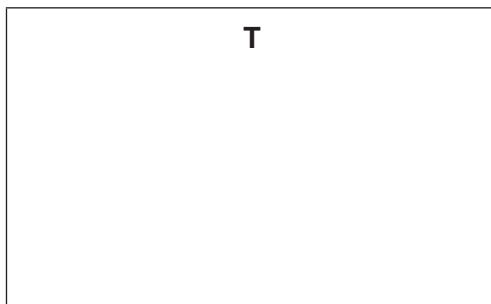
(iii) Give the balanced equation for the reaction of $(\text{CH}_3)_3\text{CCHO}$ with NaBH_4 to form **S**.

Use $[\text{H}]$ to represent an atom of hydrogen provided by NaBH_4 .

..... [1]

(iv) Draw the structure of the organic molecule **T** that reacts with **A**, $(\text{CH}_3)_3\text{CCO}_2\text{H}$, in reaction 2, to form **U**.

Suggest a catalyst for reaction 2.



catalyst [2]

(c) **X**, **Y** and **Z** are all isomers of $(\text{CH}_3)_3\text{CCHO}$.

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	$3200\text{--}3600\text{ cm}^{-1}$ 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**.

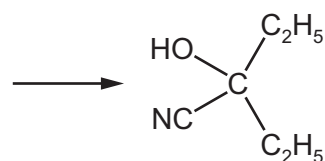
[3]

- (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.



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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