

Cambridge International AS & A Level

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CHEMISTRY

9701/21

Paper 2 AS Level Structured Questions

October/November 2020

1 hour 15 minutes

You must answer on the question paper.

You will need: Data booklet

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

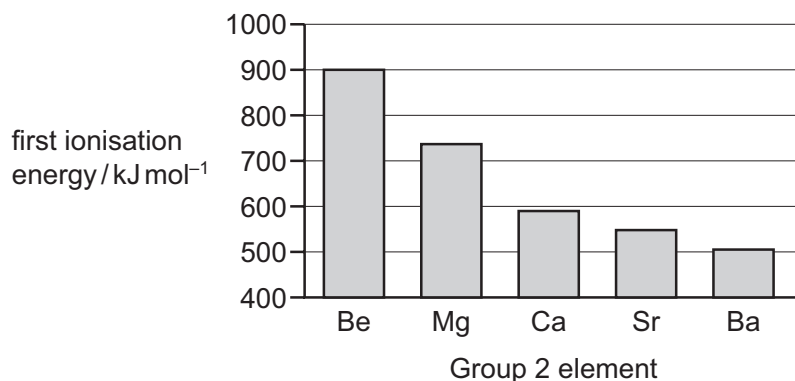
INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Blank pages are indicated.

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

- 1 The graph shows the first ionisation energies of some of the elements in Group 2.



- (a) Write an equation for the first ionisation energy of Mg.

Include state symbols.

..... [1]

- (b) Explain the observed trend in first ionisation energies down Group 2.

.....

 [3]

- (c) The second ionisation energy of Be is 1757 kJ mol⁻¹.

Explain why the second ionisation energy of Be is higher than the first ionisation energy of Be.

.....

 [2]

[Total: 6]

2 Phosphorus, sulfur and chlorine can all react with oxygen to form oxides.

(a) Phosphorus reacts with an excess of oxygen to form phosphorus(V) oxide.

(i) Write an equation to show the reaction of phosphorus with excess oxygen.

..... [1]

(ii) Describe the reaction of phosphorus(V) oxide with water.

.....

 [2]

(iii) State the structure and bonding of solid phosphorus(V) oxide.

..... [1]

(b) The two most common oxides of sulfur are SO_2 and SO_3 .

When SO_2 dissolves in water, a small proportion of it reacts with water to form a weak Brønsted-Lowry acid.

(i) Explain the meaning of the term *weak Brønsted-Lowry acid*.

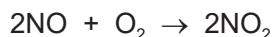
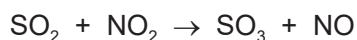
.....
 [2]

(ii) Write the equation for the reaction of SO_2 with water.

..... [1]

(iii) SO_2 reacts with NO_2 in the atmosphere to form SO_3 and NO .

NO is then oxidised in air to form NO_2 .

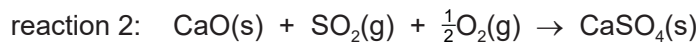
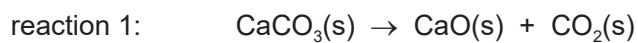


State the role of NO_2 in this two-stage process.

..... [1]

- (c) Emissions of SO_2 from coal-fired power stations can be reduced by mixing the coal with powdered limestone.

Limestone is heated to form CaO in reaction 1. This then reacts with SO_2 and O_2 to form CaSO_4 in reaction 2.



- (i) State the type of reaction occurring in reaction 1.

..... [1]

- (ii) Use the data to calculate the enthalpy change of reaction 2.

compound	$\Delta H_f / \text{kJ mol}^{-1}$
$\text{CaO}(\text{s})$	-635
$\text{SO}_2(\text{g})$	-297
$\text{CaSO}_4(\text{s})$	-1434

enthalpy change of reaction 2 = ... kJ mol^{-1} [2]

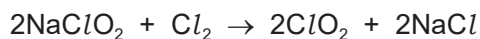
(d) Chlorine forms several oxides, including Cl_2O , ClO_2 and Cl_2O_6 .

(i) Draw a 'dot-and-cross' diagram of Cl_2O . Show outer-shell electrons only.

[1]

(ii) ClO_2 can be prepared by reacting $NaClO_2$ with Cl_2 .

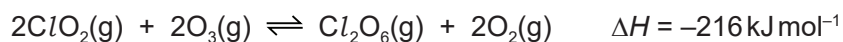
Write the oxidation state of chlorine in each species in the boxes provided.



oxidation state of chlorine:

[1]

(iii) $Cl_2O_6(g)$ is produced by the reaction of $ClO_2(g)$ with $O_3(g)$.



The reaction takes place at 500 K and 100 kPa.

State and explain the effect on the yield of $Cl_2O_6(g)$ when the experiment is carried out:

- at 1000 K and 100 kPa

.....

- at 500 K and 500 kPa.

.....

[4]

(e) Element **E** is a Period 5 element.

E reacts with oxygen to form an insoluble white oxide that has a melting point of 1910°C . The oxide of **E** conducts electricity only when liquid.

E also reacts readily with $\text{Cl}_2(\text{g})$ to form a white solid that reacts exothermically with water. The resulting solution reacts with aqueous silver nitrate to form a white precipitate that dissolves in dilute ammonia.

(i) Suggest the type of bonding shown by the **oxide** of **E**. Explain your answer.

.....
.....
..... [2]

(ii) Suggest the type of bonding shown by the **chloride** of **E**. Explain your answer.

.....
.....
..... [2]

[Total: 21]

Question 3 starts on the next page.

- 3 The reducing agent LiAlH_4 can be synthesised by reacting aluminium chloride with lithium hydride, LiH .

(a) (i) At 200°C , aluminium chloride exists as $\text{Al}_2\text{Cl}_6(\text{g})$.

Draw the structure of $\text{Al}_2\text{Cl}_6(\text{g})$, showing fully any coordinate (dative covalent) bonds in the molecule.

[2]

(ii) At 1000°C , aluminium chloride exists as $\text{AlCl}_3(\text{g})$.

State the bond angle in $\text{AlCl}_3(\text{g})$.

..... $^\circ$ [1]

(iii) Lithium hydride contains the ions Li^+ and H^- .

State the electronic configuration of these two ions.

Li^+ H^- [1]

(iv) LiAlH_4 decomposes slowly to form $\text{LiAl}(\text{s})$ and $\text{H}_2(\text{g})$.



$\text{LiAl}(\text{s})$ shows metallic bonding.

Describe metallic bonding.

.....

 [1]

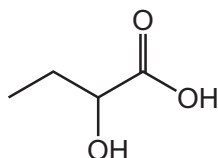
- (b) LiAlH_4 cannot be used in aqueous solution because it reacts with water to produce LiOH(aq) , $\text{H}_2(\text{g})$ and a white precipitate which is soluble in excess sodium hydroxide.

Identify the white precipitate.

..... [1]

- (c) Two students try to prepare 2-hydroxybutanoic acid in the laboratory.

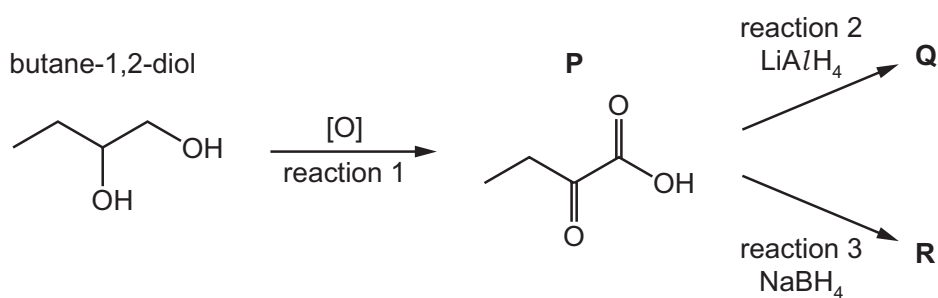
2-hydroxybutanoic acid



Both students oxidise butane-1,2-diol to form **P** in reaction 1.

One student then reduces **P** using LiAlH_4 . **Q** is formed.

The other student reduces **P** using NaBH_4 . **R** is formed.



- (i) State the reagents and conditions required for reaction 1.

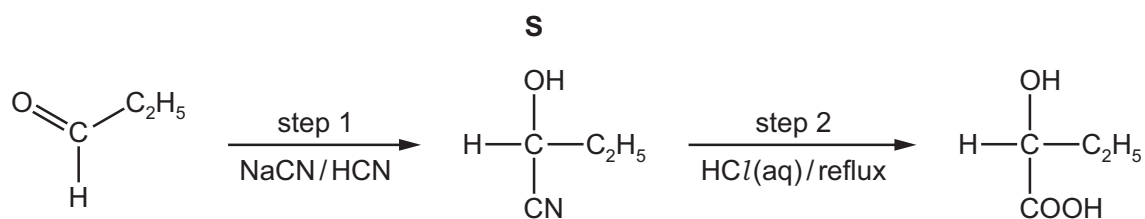
..... [2]

- (ii) Only one of the students successfully prepares 2-hydroxybutanoic acid.

Identify which of **Q** or **R** is 2-hydroxybutanoic acid and explain the difference between reactions 2 and 3.

..... [2]

A third student prepares 2-hydroxybutanoic acid using propanal as the starting material. In step 1 the student reacts propanal with a mixture of NaCN and HCN.

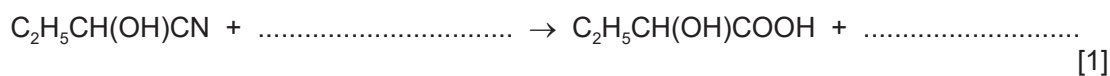


(iii) Draw the mechanism for the reaction of propanal with the mixture of NaCN and HCN to form **S**.

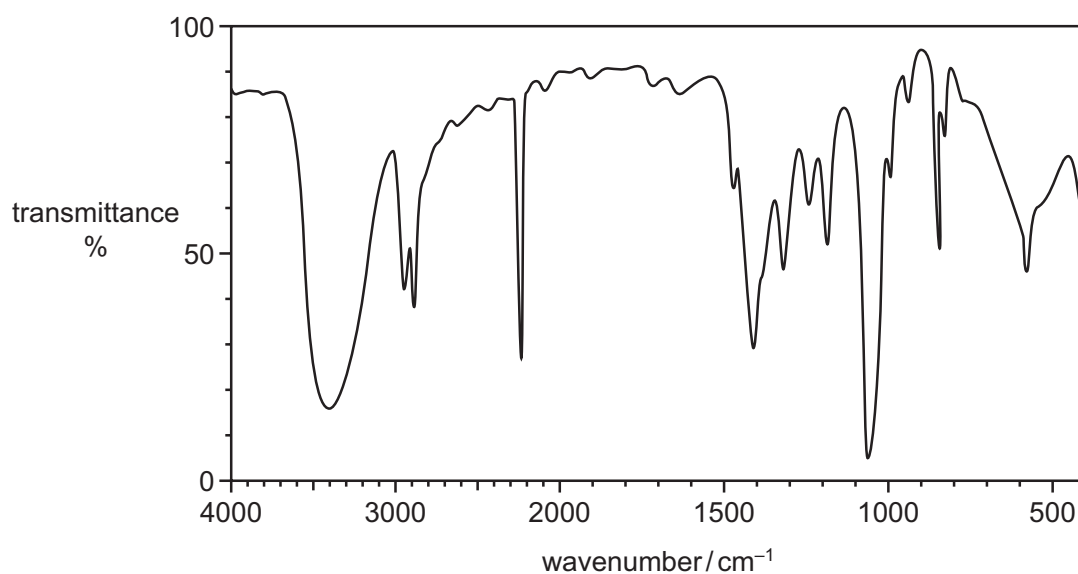
- Identify the ion that reacts with propanal.
- Draw the structure of the intermediate of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.



(iv) Complete the equation for the reaction in step 2, when **S** is heated under reflux with HCl(aq).



- (v) The infrared spectrum of an organic compound is shown. The organic compound is either **S** or 2-hydroxybutanoic acid.



Deduce the identity of the compound. Give **two** reasons for your answer.

In your answer, identify any relevant absorptions **above 1500 cm⁻¹** in the spectrum and the bonds that correspond to these absorptions.

.....

.....

.....

.....

..... [2]

[Total: 17]

4 Iodine is used in many inorganic and organic reactions.

(a) (i) State and explain the trend in volatility of the halogens, from chlorine to iodine.

.....

 [2]

(ii) Explain why HI is the **least** thermally stable of HCl, HBr and HI.

.....
 [1]

(iii) The table shows the electronegativity values for hydrogen, fluorine and iodine.

element	electronegativity value
H	2.1
F	4.0
I	2.5

Explain, in terms of intermolecular forces, why HI has a lower boiling point than HF.

.....

 [2]

(iv) Iodine reacts with hot concentrated aqueous sodium hydroxide in the same way as chlorine.

Write an equation for the reaction of iodine and hot aqueous sodium hydroxide.

..... [1]

(b) Iodoalkanes contain carbon-iodine bonds.

The simplest iodoalkane is CH_3I .

(i) CH_3I can be made from methanol, CH_3OH .

Identify a reagent that can convert CH_3OH to CH_3I .

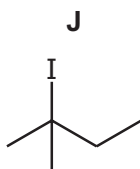
..... [1]

(ii) 1,2-diiodoethane, $\text{CH}_2\text{ICH}_2\text{I}$, can be made by bubbling ethene into liquid iodine.

Fully name the type of mechanism shown in this reaction.

..... [1]

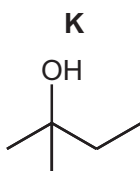
(c) **J** reacts with NaOH , forming different products dependent on the conditions used.



(i) Name **J**.

..... [1]

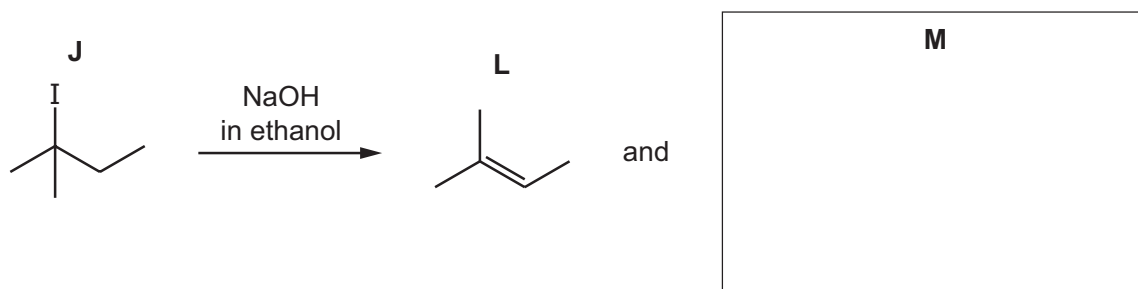
(ii) **J** reacts with NaOH(aq) to form **K**.



Fully name the mechanism of the reaction of **J** with NaOH(aq) to form **K**.

..... [1]

- (iii) **J** reacts with NaOH dissolved in ethanol to form a mixture of two alkenes, **L** and **M**. Alkene **L** is shown.



In the box provided, draw the structure of **M**. [1]

- (iv) Explain why **L** does **not** show geometrical (cis-trans) isomerism.

.....

 [1]

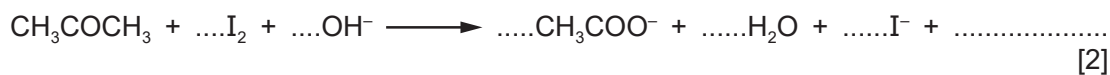
- (v) **L** reacts with hot concentrated acidified $\text{KMnO}_4(\text{aq})$ to form propanone and one other organic product.

Identify the other organic product.

..... [1]

- (vi) Propanone reacts with excess alkaline aqueous iodine.

Complete and balance the equation for this reaction.



- (vii) State **one** observation that can be made in the reaction in (c)(vi).

..... [1]

[Total: 16]

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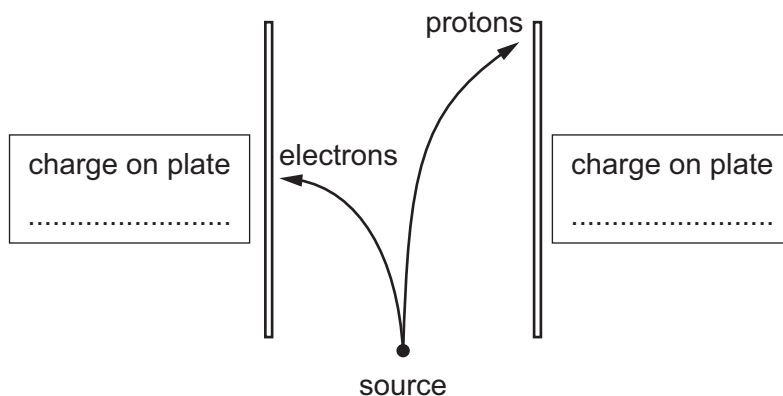
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Answer **all** the questions in the spaces provided.

- 1** Atoms contain the subatomic particles electrons, protons and neutrons. Protons and electrons were discovered by observations of their behaviours in electric fields.

- (a)** The diagram shows the behaviour of separate beams of electrons and protons in an electric field.

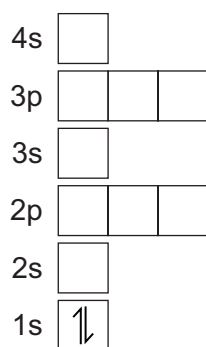


- (i)** Complete the diagram with the relative charge of each of the electrically charged plates. [1]
- (ii)** On the diagram, draw a line to show how a separate beam of neutrons from the same source behaves in the same electric field. [1]
- (b)** Electrons in atoms up to $_{36}\text{Kr}$ are distributed in s, p and d orbitals.
- (i)** State the number of occupied orbitals in an isolated atom of $_{36}\text{Kr}$.

type of orbital	s	p	d
number of orbitals			

[3]

- (ii) Complete the diagram to show the number and relative energies of the electrons in an isolated atom of $_{14}\text{Si}$.



[2]

- (iii) The diagram shows a type of orbital.



State the total number of electrons that exist in all orbitals of this type in an atom of $_9\text{F}$.

..... [1]

- (iv) The first ionisation energies of elements in the first row of the d block ($_{21}\text{Sc}$ to $_{29}\text{Cu}$) are very similar. For all these elements, it is a 4s electron that is lost during the first ionisation.

Suggest why the first ionisation energies of these elements are very similar.

.....

.....

.....

..... [3]

- (c) *Hydron* is a general term used to represent the ions $^1_1\text{H}^+$, $^2_1\text{H}^+$ and $^3_1\text{H}^+$.

State, in terms of subatomic particles in the nucleus, what is the same about each of these ions and what is different.

same

different

[1]

[Total: 12]

2 The Period 3 elements, Na to S, all react with oxygen to form oxides.

(a) State the trend in acid/base behaviour of the oxides of the Period 3 elements, from Na to S.

.....
 [1]

(b) State and explain the trend, from Na to S, in the maximum oxidation number of the Period 3 elements in their oxides.

.....

 [2]

(c) Sodium oxide and phosphorus(V) oxide both react with water.

Name the product of each reaction.

reaction	product
sodium oxide with water	
phosphorus(V) oxide with water	

[2]

(d) Explain why phosphorus(V) oxide has a low melting point of approximately 300 °C but magnesium oxide has a high melting point of approximately 2850 °C.

.....

 [3]

(e) Aluminium oxide, Al_2O_3 , reacts separately with both acids and alkalis.

(i) Write an equation for the reaction of aluminium oxide with excess aqueous hydrochloric acid.

..... [1]

(ii) Write an equation for the reaction of aluminium oxide with excess aqueous sodium hydroxide.

..... [1]

(f) Describe the lattice structure of silicon(IV) oxide.

Your answer should include reference to the arrangement of the silicon and oxygen atoms and the bonds between them.

.....
.....
.....
..... [2]

(g) Sodium oxide and silicon(IV) oxide react to form sodium silicate(IV), Na_2SiO_3 .

Sodium oxide is obtained from the thermal decomposition of sodium carbonate.

Write equations for the following reactions:

(i) sodium oxide with silicon(IV) oxide

..... [1]

(ii) the thermal decomposition of sodium carbonate, forming sodium oxide and carbon dioxide.

..... [1]

[Total: 14]

3 PCl_5 , PCl_3 and NCl_3 are halides of Group 15 elements.

(a) PCl_5 can be formed from the reaction of phosphorus with chlorine. PCl_5 has a melting point of 161°C .

(i) Write an equation for the formation of PCl_5 from the reaction of phosphorus and chlorine.

..... [1]

(ii) State the type of structure and bonding shown by liquid PCl_5 .

..... [1]

(b) A small amount of PCl_5 is added to excess water. The PCl_5 reacts vigorously to form a colourless solution.

(i) Give **one** other observation you would make when PCl_5 reacts with excess water.

..... [1]

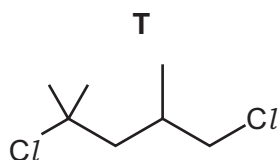
(ii) Write the equation for the reaction of PCl_5 with excess water.

..... [1]

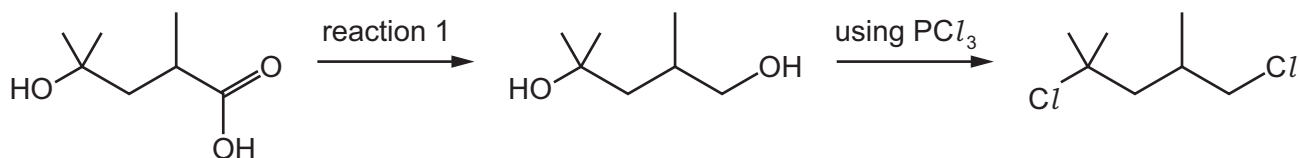
(iii) Estimate the pH of the resulting solution.

..... [1]

(c) PCl_3 is used to convert alcohols to chloroalkanes, such as compound **T**.



A possible synthesis of **T** is shown.

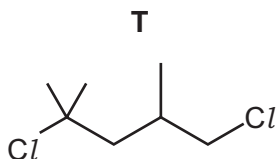


(i) Identify a reagent that could be used in reaction 1.

..... [1]

- (ii) **T** exhibits optical isomerism.

Explain what is meant by the term *optical isomer* and circle any atom(s) in **T** that give rise to optical isomerism.



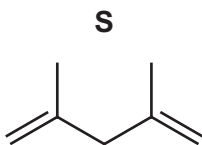
.....

.....

.....

[2]

- (iii) **T** is a **minor** product in the reaction of compound **S** with excess HCl .



Draw the structure of the **major** product of the reaction of **S** with excess HCl .

[1]

(d) NCl_3 is a yellow liquid that can be used to bleach flour.

(i) Predict the shape of the NCl_3 molecule and the Cl-N-Cl bond angle.

shape

bond angle

[2]

(ii) NCl_3 reacts with water to form HOCl , a weak Brønsted-Lowry acid.

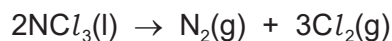
Explain fully what is meant by the term *weak Brønsted-Lowry acid*.

.....

.....

..... [2]

(iii) $\text{NCl}_3(\text{l})$ decomposes according to the equation shown.



A sealed container of volume 250 cm^3 contains an unreactive gas at a pressure of $1.00 \times 10^5 \text{ Pa}$.

0.241 g of $\text{NCl}_3(\text{l})$ was injected into the sealed container.

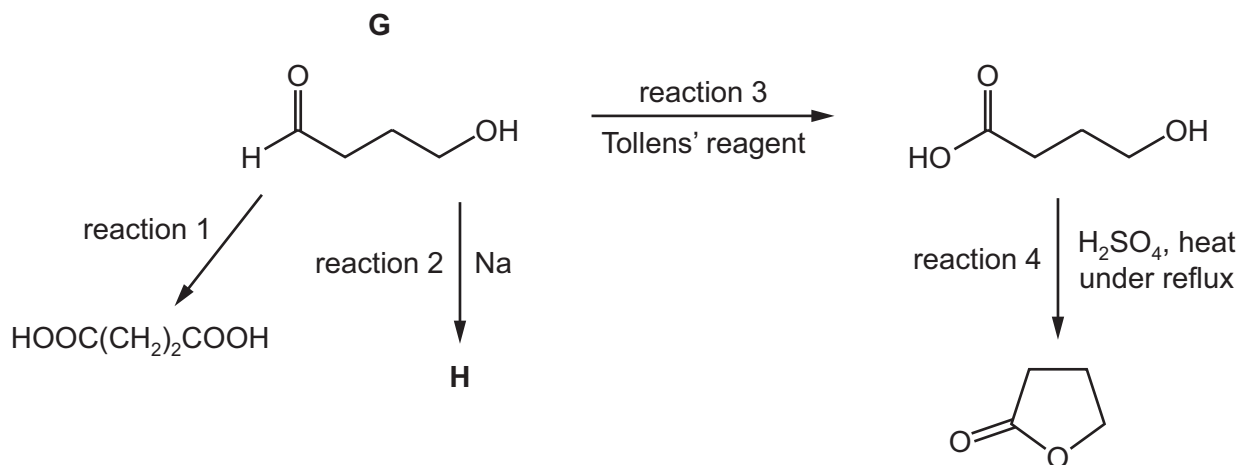
The sealed container was heated to make the $\text{NCl}_3(\text{l})$ decompose fully and then cooled to 20°C .

Calculate the final **total** pressure inside the sealed container at 20°C after the $\text{NCl}_3(\text{l})$ has fully decomposed.

final **total** pressure = ... Pa
[4]

[Total: 17]

4 Some reactions of compound **G** are shown.



(a) (i) State the type of reaction that occurs in reaction 1.

..... [1]

(ii) Suggest the reagent(s) and conditions required for reaction 1.

.....

..... [2]

(iii) Draw the structure of the organic product, **H**, from reaction 2.

[1]

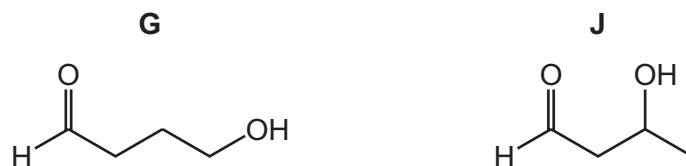
(iv) State what you would observe in reaction 3.

..... [1]

(v) Give the type of reaction shown by reaction 4.

..... [1]

(b) **G** and **J** are structural isomers of each other.



(i) Name the type of structural isomerism shown by **G** and **J**.

..... [1]

(ii) Suggest **one** chemical test that can distinguish **G** from **J**. Give the result of the test with each compound.

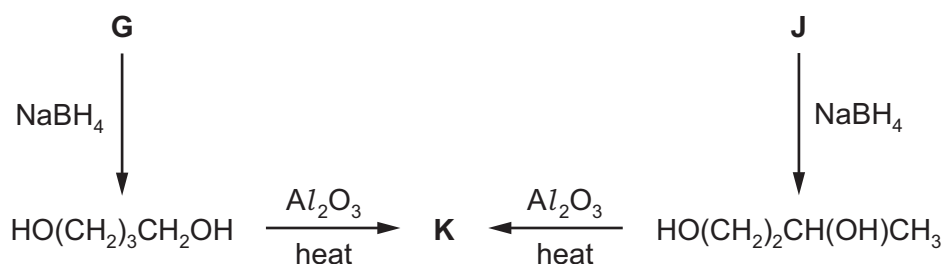
test

result with **G**

result with **J**

[2]

In the reaction schemes below, **G** and **J** are converted into organic compound **K**.



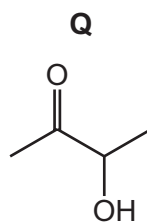
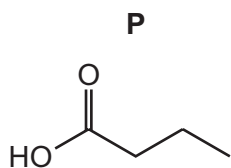
(iii) State the role of NaBH₄ in the reactions with **G** and **J**.

..... [1]

(iv) Identify the organic product **K**.

..... [1]

(c) **P** and **Q** have the same molecular formula as **G**.

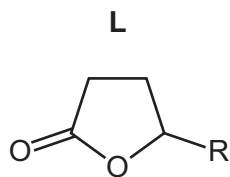


Complete the table with the expected observations for the reactions of **P** and **Q** with the named reagents.

reagent	result with P	result with Q
$\text{Br}_2(\text{aq})$		
2,4-dinitrophenylhydrazine		
aqueous sodium carbonate		

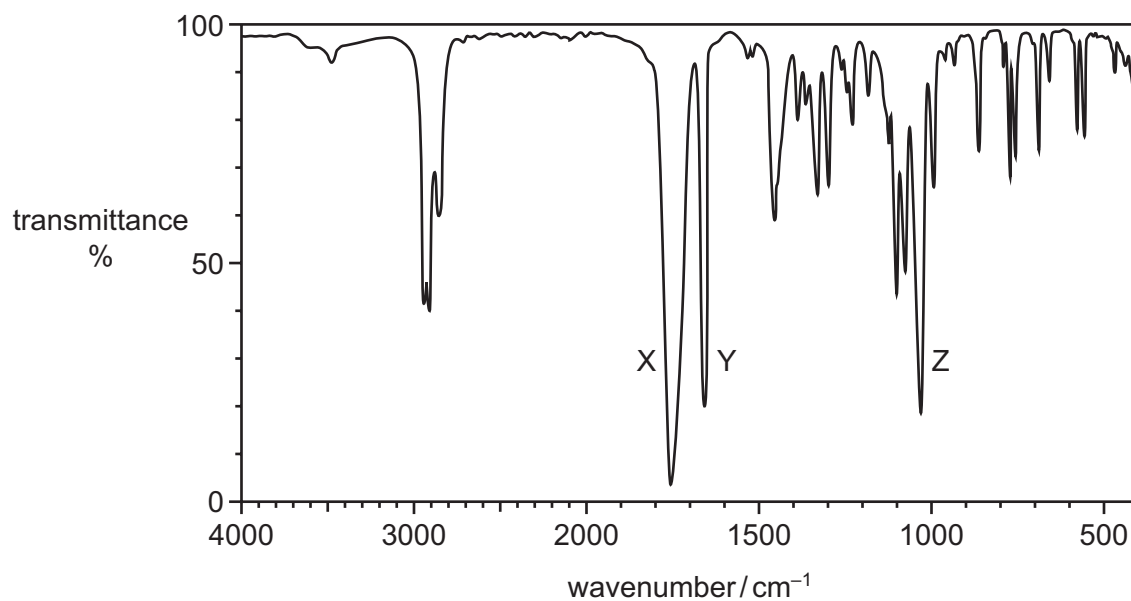
[3]

(d) The structure of compound **L** is shown. R represents a hydrocarbon chain.



A student was asked to deduce the full structure of **L**.

The student analysed **L** using infrared spectroscopy. The following spectrum was obtained.



(i) Identify the bonds responsible for the absorptions marked X and Z.

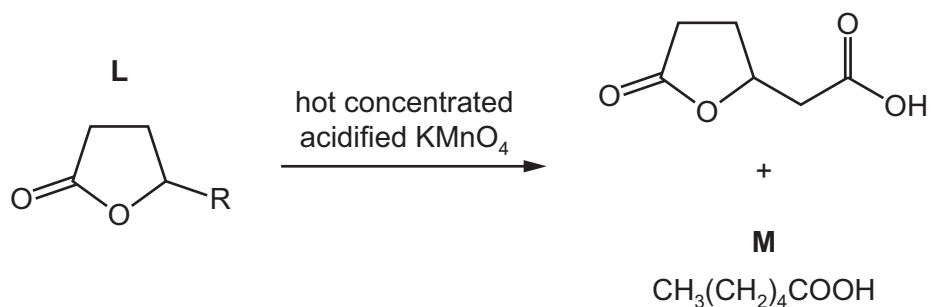
X

Z

[1]

Absorption Y shows that **L** has a C=C bond present in the R group.

The student decided to treat **L** with hot concentrated acidified potassium manganate(VII). The products of the reaction are shown.



(ii) Name **M**.

..... [1]

(iii) Use the information in (d) to deduce the molecular formula of **L**.

molecular formula of **L** = ... [1]

[Total: 17]

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NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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9701/23

October/November 2020

1 hour 15 minutes

You must answer on the question paper.

You will need: Data booklet

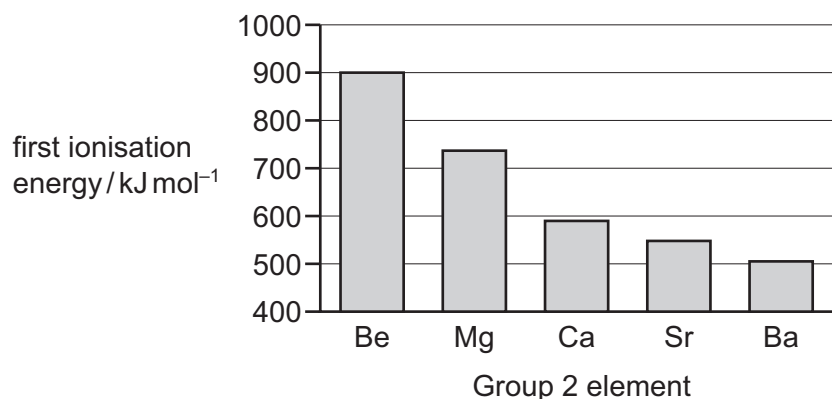
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Blank pages are indicated.

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

- 1 The graph shows the first ionisation energies of some of the elements in Group 2.



- (a) Write an equation for the first ionisation energy of Mg.

Include state symbols.

..... [1]

- (b) Explain the observed trend in first ionisation energies down Group 2.

.....
.....
.....
.....
.....
..... [3]

- (c) The second ionisation energy of Be is 1757 kJ mol⁻¹.

Explain why the second ionisation energy of Be is higher than the first ionisation energy of Be.

.....
.....
.....
.....
..... [2]

[Total: 6]

2 Phosphorus, sulfur and chlorine can all react with oxygen to form oxides.

(a) Phosphorus reacts with an excess of oxygen to form phosphorus(V) oxide.

(i) Write an equation to show the reaction of phosphorus with excess oxygen.

..... [1]

(ii) Describe the reaction of phosphorus(V) oxide with water.

.....

.....

..... [2]

(iii) State the structure and bonding of solid phosphorus(V) oxide.

..... [1]

(b) The two most common oxides of sulfur are SO_2 and SO_3 .

When SO_2 dissolves in water, a small proportion of it reacts with water to form a weak Brønsted-Lowry acid.

(i) Explain the meaning of the term *weak Brønsted-Lowry acid*.

.....

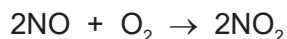
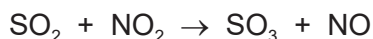
..... [2]

(ii) Write the equation for the reaction of SO_2 with water.

..... [1]

(iii) SO_2 reacts with NO_2 in the atmosphere to form SO_3 and NO .

NO is then oxidised in air to form NO_2 .

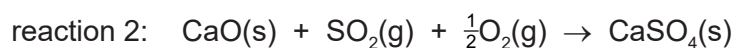
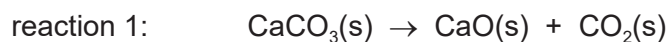


State the role of NO_2 in this two-stage process.

..... [1]

- (c) Emissions of SO_2 from coal-fired power stations can be reduced by mixing the coal with powdered limestone.

Limestone is heated to form CaO in reaction 1. This then reacts with SO_2 and O_2 to form CaSO_4 in reaction 2.



- (i) State the type of reaction occurring in reaction 1.

..... [1]

- (ii) Use the data to calculate the enthalpy change of reaction 2.

compound	$\Delta H_f / \text{kJ mol}^{-1}$
$\text{CaO}(\text{s})$	−635
$\text{SO}_2(\text{g})$	−297
$\text{CaSO}_4(\text{s})$	−1434

enthalpy change of reaction 2 = ... kJ mol^{-1} [2]

(d) Chlorine forms several oxides, including Cl_2O , ClO_2 and Cl_2O_6 .

(i) Draw a 'dot-and-cross' diagram of Cl_2O . Show outer-shell electrons only.

[1]

(ii) ClO_2 can be prepared by reacting NaClO_2 with Cl_2 .

Write the oxidation state of chlorine in each species in the boxes provided.

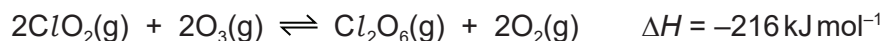


oxidation state of chlorine:

+3

[1]

(iii) $\text{Cl}_2\text{O}_6(\text{g})$ is produced by the reaction of $\text{ClO}_2(\text{g})$ with $\text{O}_3(\text{g})$.



The reaction takes place at 500 K and 100 kPa.

State and explain the effect on the yield of $\text{Cl}_2\text{O}_6(\text{g})$ when the experiment is carried out:

- at 1000 K and 100 kPa

.....

.....

.....

.....

- at 500 K and 500 kPa.

.....

.....

.....

.....

[4]

(e) Element **E** is a Period 5 element.

E reacts with oxygen to form an insoluble white oxide that has a melting point of 1910 °C. The oxide of **E** conducts electricity only when liquid.

E also reacts readily with $\text{Cl}_2(\text{g})$ to form a white solid that reacts exothermically with water. The resulting solution reacts with aqueous silver nitrate to form a white precipitate that dissolves in dilute ammonia.

(i) Suggest the type of bonding shown by the **oxide** of **E**. Explain your answer.

.....
.....
..... [2]

(ii) Suggest the type of bonding shown by the **chloride** of **E**. Explain your answer.

.....
.....
..... [2]

[Total: 21]

Question 3 starts on the next page.

- 3 The reducing agent LiAlH_4 can be synthesised by reacting aluminium chloride with lithium hydride, LiH .

(a) (i) At 200°C , aluminium chloride exists as $\text{Al}_2\text{Cl}_6(\text{g})$.

Draw the structure of $\text{Al}_2\text{Cl}_6(\text{g})$, showing fully any coordinate (dative covalent) bonds in the molecule.

[2]

(ii) At 1000°C , aluminium chloride exists as $\text{AlCl}_3(\text{g})$.

State the bond angle in $\text{AlCl}_3(\text{g})$.

..... $^\circ$ [1]

(iii) Lithium hydride contains the ions Li^+ and H^- .

State the electronic configuration of these two ions.

Li^+ H^- [1]

(iv) LiAlH_4 decomposes slowly to form $\text{LiAl}(\text{s})$ and $\text{H}_2(\text{g})$.



$\text{LiAl}(\text{s})$ shows metallic bonding.

Describe metallic bonding.

.....

 [1]

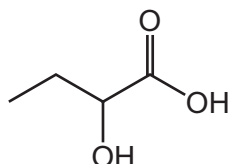
- (b) LiAlH_4 cannot be used in aqueous solution because it reacts with water to produce LiOH(aq) , $\text{H}_2(\text{g})$ and a white precipitate which is soluble in excess sodium hydroxide.

Identify the white precipitate.

..... [1]

- (c) Two students try to prepare 2-hydroxybutanoic acid in the laboratory.

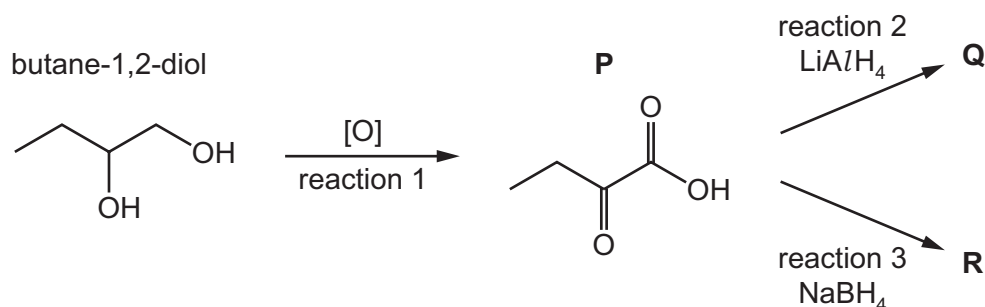
2-hydroxybutanoic acid



Both students oxidise butane-1,2-diol to form **P** in reaction 1.

One student then reduces **P** using LiAlH_4 . **Q** is formed.

The other student reduces **P** using NaBH_4 . **R** is formed.



- (i) State the reagents and conditions required for reaction 1.

.....
 [2]

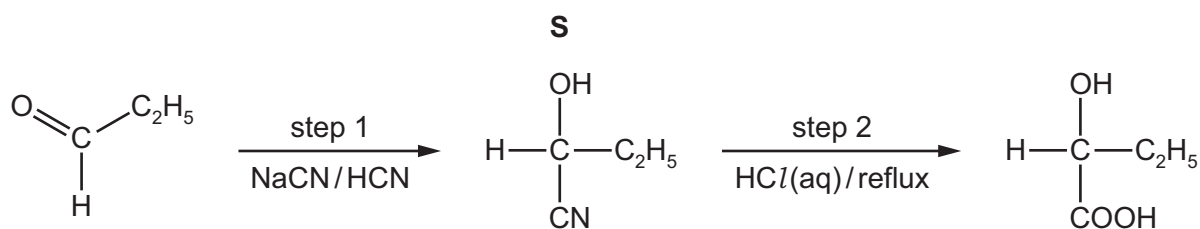
- (ii) Only one of the students successfully prepares 2-hydroxybutanoic acid.

Identify which of **Q** or **R** is 2-hydroxybutanoic acid and explain the difference between reactions 2 and 3.

.....

 [2]

A third student prepares 2-hydroxybutanoic acid using propanal as the starting material. In step 1 the student reacts propanal with a mixture of NaCN and HCN.



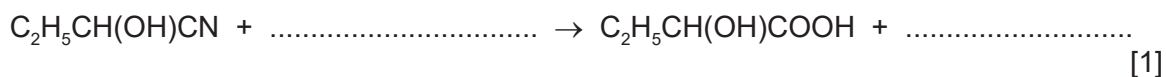
(iii) Draw the mechanism for the reaction of propanal with the mixture of NaCN and HCN to form **S**.

- Identify the ion that reacts with propanal.
- Draw the structure of the intermediate of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.



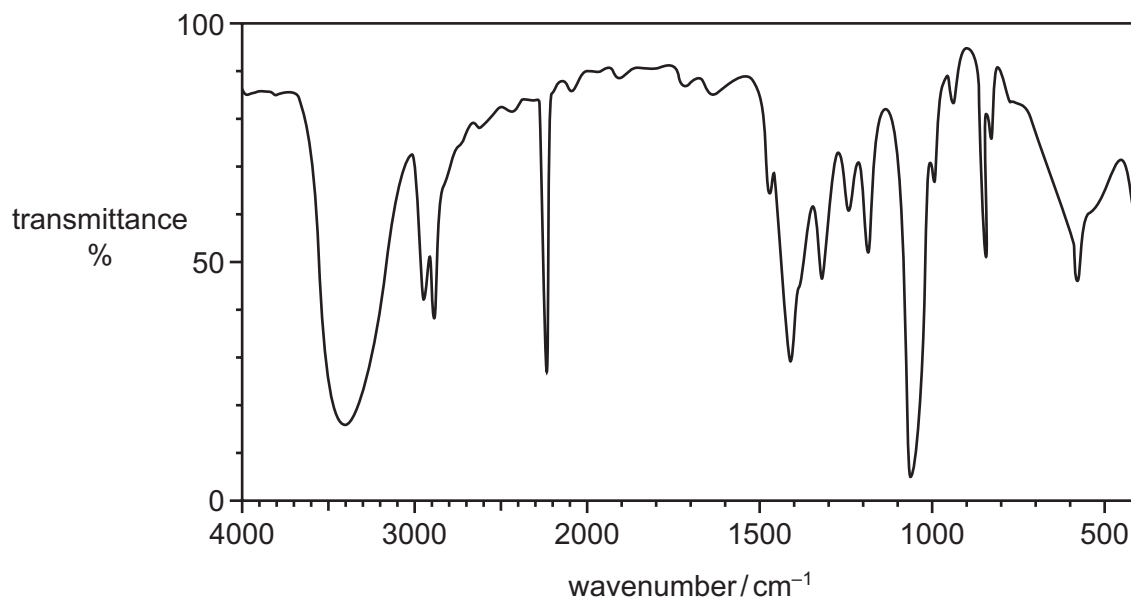
[4]

(iv) Complete the equation for the reaction in step 2, when **S** is heated under reflux with HCl(aq).



[1]

- (v) The infrared spectrum of an organic compound is shown. The organic compound is either **S** or 2-hydroxybutanoic acid.



Deduce the identity of the compound. Give **two** reasons for your answer.

In your answer, identify any relevant absorptions **above 1500 cm⁻¹** in the spectrum and the bonds that correspond to these absorptions.

.....

.....

.....

.....

..... [2]

[Total: 17]

4 Iodine is used in many inorganic and organic reactions.

(a) (i) State and explain the trend in volatility of the halogens, from chlorine to iodine.

.....

 [2]

(ii) Explain why HI is the **least** thermally stable of HCl, HBr and HI.

.....
 [1]

(iii) The table shows the electronegativity values for hydrogen, fluorine and iodine.

element	electronegativity value
H	2.1
F	4.0
I	2.5

Explain, in terms of intermolecular forces, why HI has a lower boiling point than HF.

.....

 [2]

(iv) Iodine reacts with hot concentrated aqueous sodium hydroxide in the same way as chlorine.

Write an equation for the reaction of iodine and hot aqueous sodium hydroxide.

..... [1]

(b) Iodoalkanes contain carbon-iodine bonds.

The simplest iodoalkane is CH_3I .

(i) CH_3I can be made from methanol, CH_3OH .

Identify a reagent that can convert CH_3OH to CH_3I .

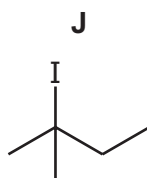
..... [1]

(ii) 1,2-diiodoethane, $\text{CH}_2\text{ICH}_2\text{I}$, can be made by bubbling ethene into liquid iodine.

Fully name the type of mechanism shown in this reaction.

..... [1]

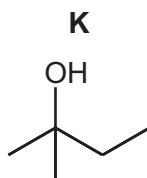
(c) **J** reacts with NaOH , forming different products dependent on the conditions used.



(i) Name **J**.

..... [1]

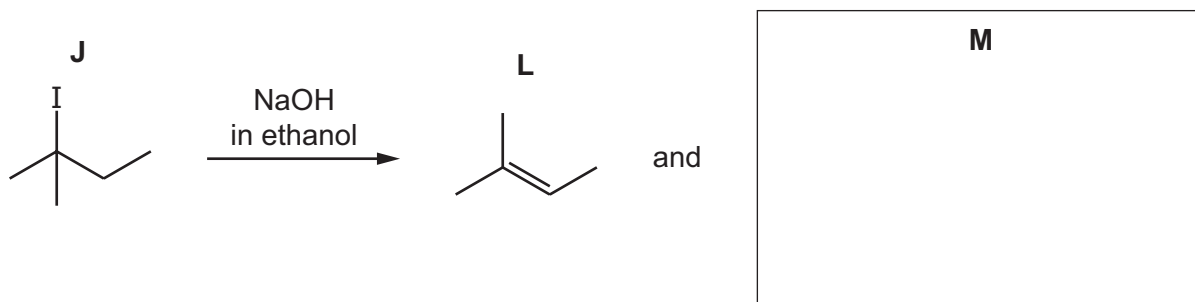
(ii) **J** reacts with NaOH(aq) to form **K**.



Fully name the mechanism of the reaction of **J** with NaOH(aq) to form **K**.

..... [1]

- (iii) **J** reacts with NaOH dissolved in ethanol to form a mixture of two alkenes, **L** and **M**. Alkene **L** is shown.



In the box provided, draw the structure of **M**.

[1]

- (iv) Explain why **L** does **not** show geometrical (cis-trans) isomerism.

.....

 [1]

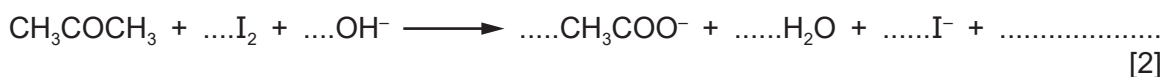
- (v) **L** reacts with hot concentrated acidified $\text{KMnO}_4(\text{aq})$ to form propanone and one other organic product.

Identify the other organic product.

..... [1]

- (vi) Propanone reacts with excess alkaline aqueous iodine.

Complete and balance the equation for this reaction.



[2]

- (vii) State **one** observation that can be made in the reaction in (c)(vi).

..... [1]

[Total: 16]

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