Cambridge Assessment
International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

2079142871

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.

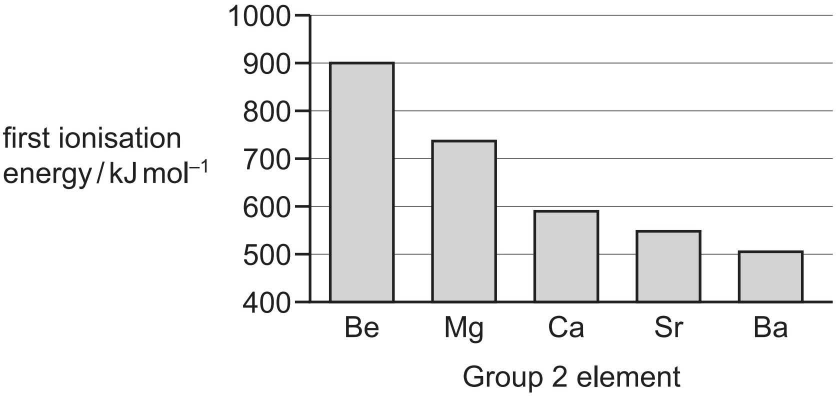
INFORMATION

- 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.

$$SO_2 + NO_2 \rightarrow SO_3 + NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

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.

reaction 1: $CaCO_3(s) \rightarrow CaO(s) + CO_2(s)$

reaction 2: $CaO(s) + SO_2(g) + \frac{1}{2}O_2(g) \rightarrow CaSO_4(s)$

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

.... [1]

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

compound	ΔH_f / kJ mol^{-1}
CaO(s)	–635
SO_2(g)	–297
$CaSO_4$(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.

$$2NaClO_2 + Cl_2 \rightarrow 2ClO_2 + 2NaCl$$

oxidation state of chlorine: $\boxed{+3}$ ☐ ☐ ☐

[1]

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

$$2ClO_2(g) + 2O_3(g) \rightleftharpoons Cl_2O_6(g) + 2O_2(g) \qquad \Delta H = -216\,kJ\,mol^{-1}$$

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 $Cl_2(g)$ 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 $Al_2Cl_6(g)$.

Draw the structure of $Al_2Cl_6(g)$, showing fully any coordinate (dative covalent) bonds in the molecule.

[2]

(ii) At 1000 °C, aluminium chloride exists as $AlCl_3(g)$.

State the bond angle in $AlCl_3(g)$.

.... ° [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 $LiAl(s)$ and $H_2(g)$.

$$LiAlH_4(s) \rightarrow LiAl(s) + 2H_2(g)$$

$LiAl(s)$ shows metallic bonding.

Describe metallic bonding.

....

....

.... [1]

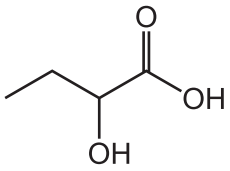
(b) $LiAlH_4$ cannot be used in aqueous solution because it reacts with water to produce LiOH(aq), H_2(g) and a white precipitate which is soluble in excess sodium hydroxide.

Identify the white precipitate.

.... [1]

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

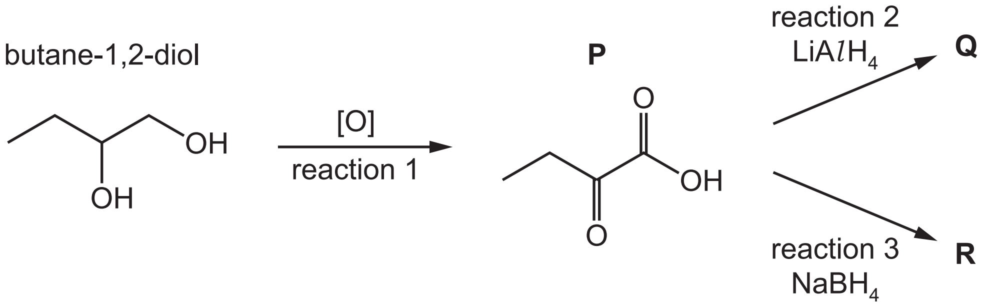
2-hydroxybutanoic acid



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.

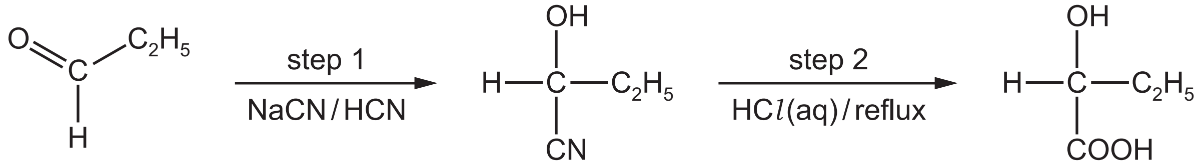
....

....

.... [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.

S



(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.

S

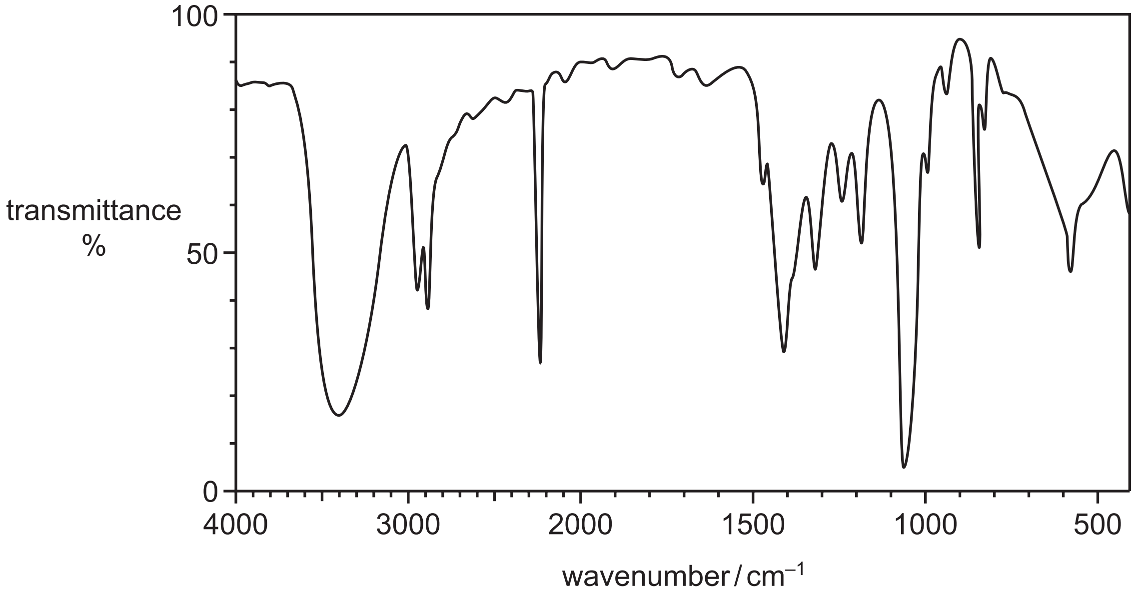
[4]

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

$C_2H_5CH(OH)CN$ + ... → $C_2H_5CH(OH)COOH$ + ...

[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 HC*l*, 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]

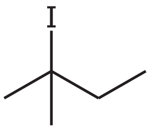
(ii) 1,2-diiodoethane, CH_2ICH_2I, can be made by bubbling ethene into liquid iodine.

Fully name the type of mechanism shown in this reaction.

.... [1]

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

J

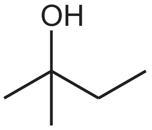


(i) Name **J**.

.... [1]

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

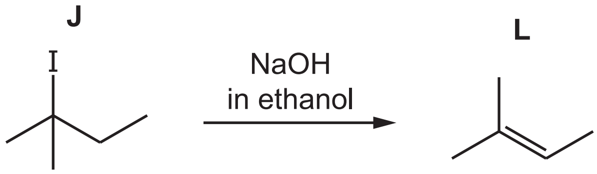
K



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.



and

M

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 $KMnO_4(aq)$ 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.

CH_3COCH_3 + ...I_2 + ...OH^- $\longrightarrow$ .....CH_3COO^- + ...H_2O + ...I^- + ...
[2]

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

.... [1]

[Total: 16]

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