Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5013508299

CHEMISTRY **9701/21**

Paper 2 AS Level Structured Questions **May/June 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 **12** pages. Blank pages are indicated.

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

1 Gallium is a metal in Group 13 of the Periodic Table.

(a) There are two stable isotopes of gallium, ^{69}Ga and ^{71}Ga.

(i) State, with reference to subatomic particles, how the isotopes ^{69}Ga and ^{71}Ga differ from each other.

.....

..... [1]

(ii) State what further information is needed to calculate the relative atomic mass of gallium.

..... [1]

(b) Gallium and its compounds show similar properties to aluminium and its compounds.
Gallium reacts with excess chlorine to form gallium trichloride.

(i) At 500 °C, gallium trichloride is a gas.

Suggest the type of attraction that exists at 500 °C

- between atoms within a gallium trichloride molecule

.....

- between gallium trichloride molecules.

.....
[2]

(ii) When gallium trichloride is cooled a solid, Ga_2Cl_6, forms.

Suggest the name of the attraction formed between two gallium trichloride molecules to form Ga_2Cl_6.

..... [1]

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(c) Gallium metal reacts rapidly when exposed to air. A white solid layer is formed on its surface.

(i) Suggest an equation to describe the reaction occurring when gallium metal is exposed to air.

..... [2]

(ii) The table gives the formula of each gallium-containing product formed when gallium oxide reacts separately with hot aqueous hydrochloric acid and hot aqueous sodium hydroxide.

	formula of gallium-containing product
hot aqueous hydrochloric acid	$GaCl_3$
hot aqueous sodium hydroxide	$NaGa(OH)_4$

Give the name of the type of behaviour shown by gallium oxide in these reactions.

..... [1]

[Total: 8]

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[Turn over

2 **(a)** The equation shown in **(a)(i)** describes the reaction which occurs when aqueous potassium iodide is added to aqueous copper(II) sulfate. A white precipitate of copper(I) iodide forms in a brown solution of iodine and potassium sulfate.

(i) Balance the equation and include state symbols.

.....$CuSO_4$(.....) + ...KI(.....) → .....CuI(.....) + ...I_2(.....) + ...K_2SO_4(.....)

[2]

The table gives the oxidation numbers of iodine in the different species in the equation.

iodine-containing species	oxidation number of iodine
KI	–1
CuI	–1
I_2	0

(ii) Deduce the oxidation number of copper in $CuSO_4$ and CuI.

- oxidation number of copper in $CuSO_4$ .....
- oxidation number of copper in CuI .....

[1]

(iii) Describe the type of reaction shown by the equation in **(a)(i)**. Explain your answer in terms of electron transfer.

.....

.....

..... [2]

(b) In the reaction described in **(a)(i)**, a student uses 17.43 g of $CuSO_4$•**y**H_2O. By further titration of the reaction products the student concludes that the total amount of $CuSO_4$ in the sample is 0.0982 mol.

Use the *Data Booklet* to complete the table to calculate the value of **y**, where **y** is an integer. Show your working.

mass of 0.0982 mol $CuSO_4$	..... g
amount of H_2O in 17.43 g of $CuSO_4$•**y**H_2O	..... mol H_2O
value of **y**	**y** = ...

[4]

[Total: 9]

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3 Nitric acid, HNO_3, can be made by reacting nitrogen dioxide with water.

The enthalpy change for the reaction can be measured indirectly using a Hess' cycle.

$$3NO_2(g) + H_2O(l) \xrightarrow{\Delta H_r} 2HNO_3(l) + NO(g)$$

(a) Explain what is meant by the term *enthalpy change of formation*.

.....

.....

..... [2]

(b) Complete the Hess' cycle using the values given in the table and hence calculate the enthalpy change, ΔH_r, for this reaction.

Show your working.

substance	ΔH_f / kJ mol^{-1}
$NO_2(g)$	34.0
$H_2O(l)$	–286
$HNO_3(l)$	–173
NO(g)	91.1

$$3NO_2(g) + H_2O(l) \xrightarrow{\Delta H_r} 2HNO_3(l) + NO(g)$$

ΔH_r = ... kJ mol^{-1}
[3]

(c) Nitrogen and oxygen do not react at normal atmospheric temperatures.

Explain why.

.....

.....

.....

..... [2]

Nitrogen oxides can be formed naturally in the Earth's atmosphere from nitrogen and oxygen in the air.

(d) State **one** way that nitrogen oxides are produced naturally.

..... [1]

(e) Nitrogen dioxide, NO_2, acts as a homogeneous catalyst in the oxidation of atmospheric sulfur dioxide.

(i) Explain why NO_2 is described as a homogeneous catalyst.

.....

.....

.....

..... [3]

(ii) Write equations which describe the two reactions occurring when NO_2 acts as a catalyst in the formation of sulfur trioxide from sulfur dioxide.

.....

..... [2]

[Total: 13]

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4 Calcium nitrate, $Ca(NO_3)_2$, reacts with ammonia, carbon dioxide and water to form a mixture of ammonium nitrate and calcium carbonate.

$$Ca(NO_3)_2 + 2NH_3 + CO_2 + H_2O \rightarrow 2NH_4NO_3 + CaCO_3$$

(a) Explain why ammonia is described as a Brønsted-Lowry base in this reaction.

..... [1]

The product mixture can then be added to soil.

(b) State **two** reasons why this mixture of products is added to some soils.

1 .....

2 .....

[2]

(c) Complete the table to name the shape and give the bond angle of each species.

	name of shape	bond angle / °
CO_2		
NH_3		
H_2O		

[3]

[Total: 6]

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[Turn over

5 **(a)** Below is a list of species which can react with organic compounds.

CN^- HCl Cl H_2O CO_3^{2-}

(i) From the list, identify a species which can react with ethane.

..... [1]

(ii) From the list, identify **two** species which can attack the π bond in ethene.

..... [1]

(iii) From the list, identify a species which can be used to distinguish between solutions of propanoic acid and propan-1-ol. Describe any relevant observations.

.....

.....

..... [2]

(b) Cl(g) can be made from Cl_2(g).

(i) Describe the conditions required for this process.

..... [1]

(ii) Name this process.

..... [1]

(c) **(i)** Name an organic functional group which reacts with a nucleophile in an addition reaction.

..... [1]

(ii) Name an organic functional group which tends to react with a nucleophile in an S_N1 substitution mechanism.

..... [1]

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(d) But-1-ene reacts with steam in the presence of concentrated phosphoric acid to form two isomers of molecular formula $C_4H_{10}O$.

Each reaction occurs via a different intermediate ion.

(i) Draw the structure of both intermediate ions.

[2]

(ii) Circle the more stable intermediate ion drawn in **(d)(i)**. Explain your answer.

.....

.....

..... [2]

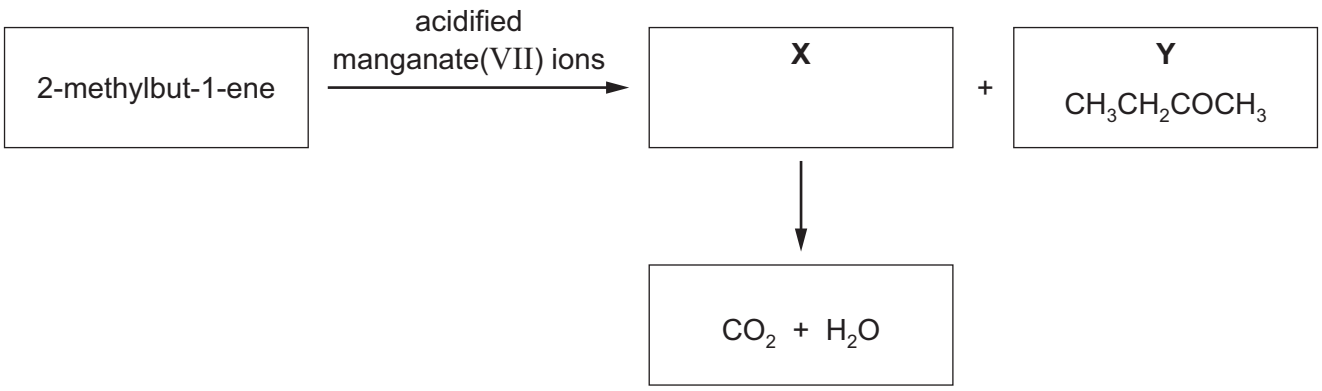
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[Turn over

6 2-methylbut-1-ene reacts with acidified manganate(VII) ions, under specific conditions, to produce two organic compounds **X** and **Y**.

X immediately reacts with the acidified manganate(VII) ions to form carbon dioxide and water. **Y** has the structural formula $CH_3CH_2COCH_3$.



(a) Draw the skeletal formula of 2-methylbut-1-ene.

[1]

(b) (i) State the specific conditions required for the acidified manganate(VII) ions to react with 2-methylbut-1-ene in this way.

..... [1]

(ii) Name the type of reaction occurring to the functional group in 2-methylbut-1-ene in the reaction in **(b)(i)**.

..... [1]

(c) Draw the structural formula of **X**.

..... [1]

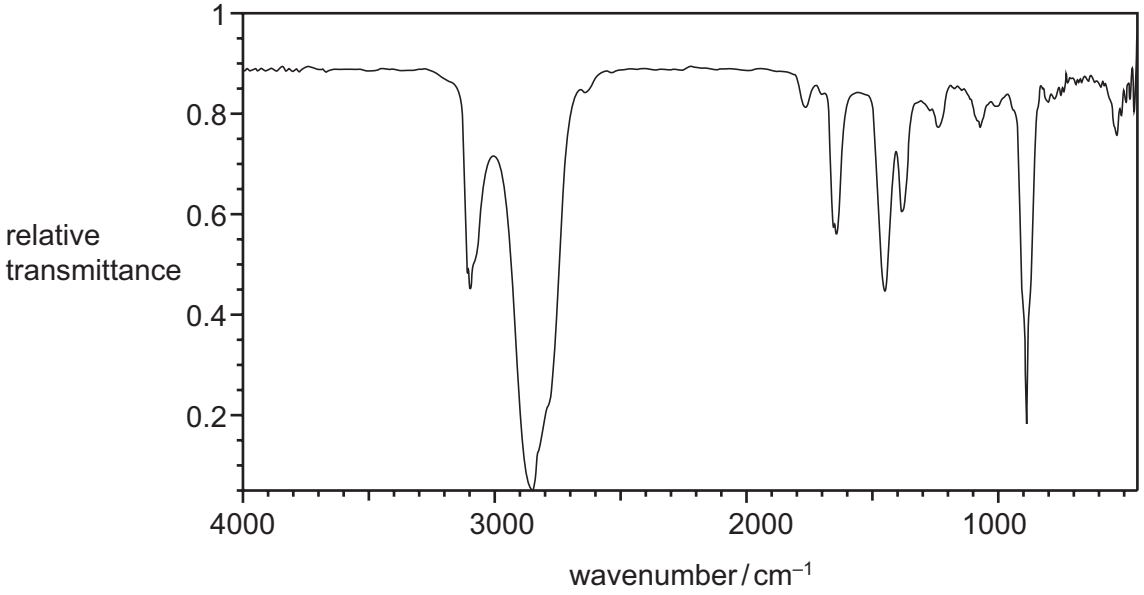
(d) Describe a chemical test and the expected observation(s) to confirm the presence of the carbonyl functional group in **Y**.

.....

..... [2]

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(e) The infra-red spectrum of 2-methylbut-1-ene is shown.



Predict two main differences that would be seen between the spectra of **Y**, $CH_3CH_2COCH_3$, and of 2-methylbut-1-ene. Give reasons for your predictions.

Your answer should refer only to the region of each spectrum **above 1500 cm^{-1}**.

.....

.....

.....

.....

..... [2]

(f) Propanoic acid, $CH_3CH_2CO_2H$, is reduced by $LiAlH_4$.

(i) Write an equation to show this reaction. Use [H] to represent an atom of hydrogen from the reducing agent.

..... [1]

(ii) Name the organic product formed in this reaction.

..... [1]

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[Turn over

(g) Organic compound **W** is an ester which is a structural isomer of propanoic acid.

(i) State the molecular formula of **W**.

..... [1]

(ii) Draw a possible structure of **W**.

[1]

[Total: 12]

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