



Cambridge International AS & A Level

CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

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.



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]

- (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	$\text{NaGa}(\text{OH})_4$

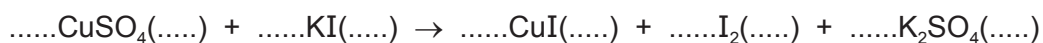
Give the name of the type of behaviour shown by gallium oxide in these reactions.

..... [1]

[Total: 8]

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.



[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 CuSO₄ and CuI.

- oxidation number of copper in CuSO₄
- 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 CuSO₄·yH₂O. By further titration of the reaction products the student concludes that the total amount of CuSO₄ 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.

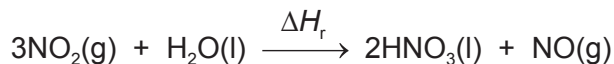
mass of 0.0982 mol CuSO ₄ g
amount of H ₂ O in 17.43 g of CuSO ₄ ·yH ₂ O mol H ₂ O
value of y	y =

[4]

[Total: 9]

3 Nitric acid, HNO₃, can be made by reacting nitrogen dioxide with water.

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



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

.....

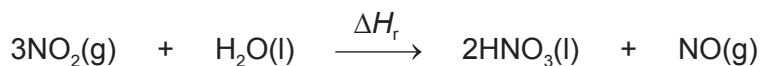
.....

..... [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	$\Delta H_f / \text{kJ mol}^{-1}$
NO ₂ (g)	34.0
H ₂ O(l)	-286
HNO ₃ (l)	-173
NO(g)	91.1



$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$
[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.

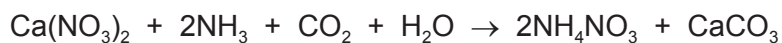
.....
.....
.....
..... [3]

(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]

- 4 Calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, reacts with ammonia, carbon dioxide and water to form a mixture ammonium nitrate and calcium carbonate.



- (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]

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



(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) $\text{Cl}(\text{g})$ can be made from $\text{Cl}_2(\text{g})$.

(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 $\text{S}_{\text{N}}1$ substitution mechanism.

..... [1]

(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]

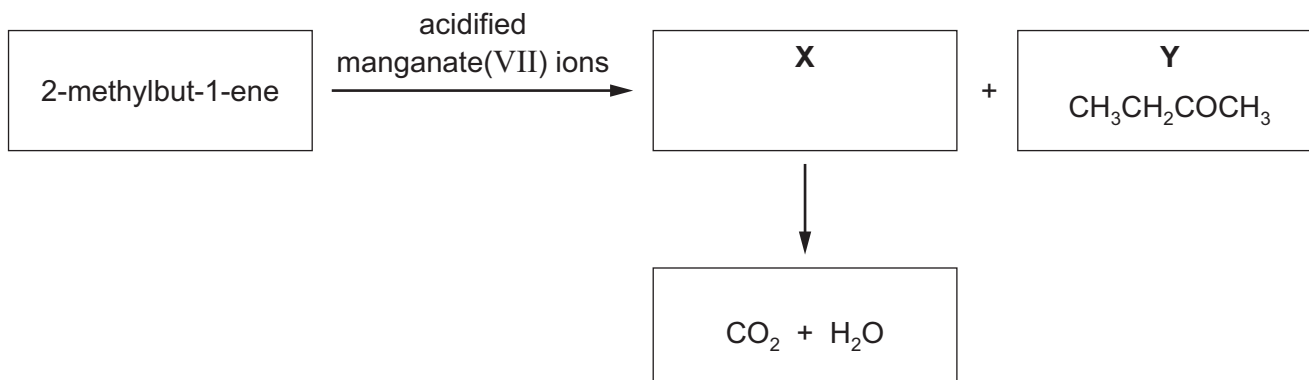
(ii) Circle the more stable intermediate ion drawn in (d)(i). Explain your answer.

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

[Total: 12]

- 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 $\text{CH}_3\text{CH}_2\text{COCH}_3$.



- (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]

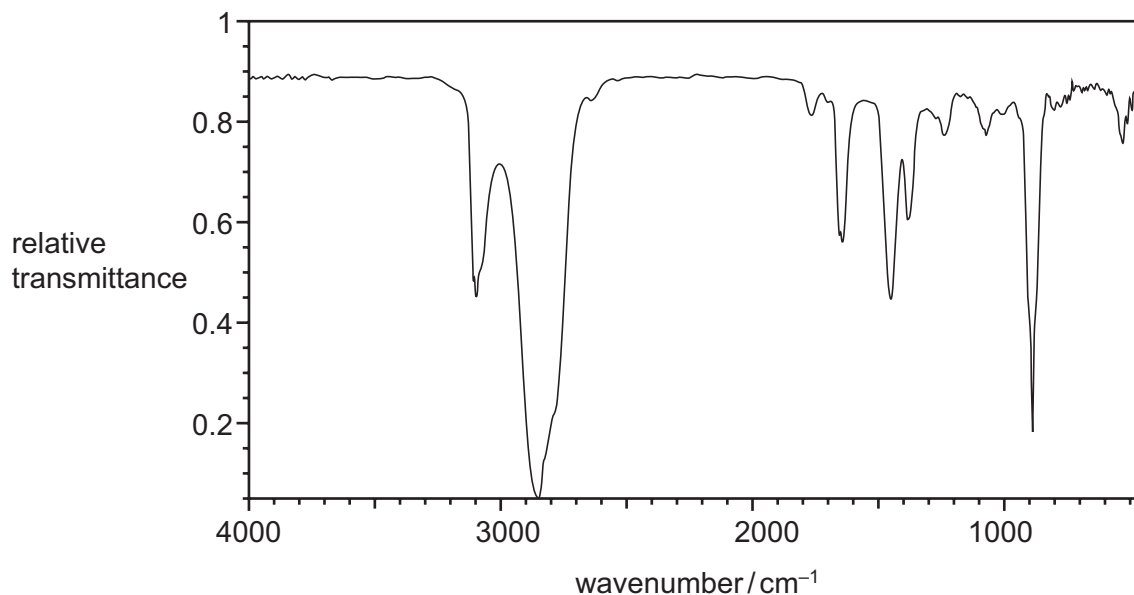
- (c) Draw the structural formula of **X**.

..... [1]

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

.....
 [2]

(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**, $\text{CH}_3\text{CH}_2\text{COCH}_3$, 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, $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$, 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]

(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]

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge Assessment International Education is part of the Cambridge Assessment Group. Cambridge Assessment is the brand name of the University of Cambridge Local Examinations Syndicate (UCLES), which itself is a department of the University of Cambridge.