

**Cambridge IGCSE™ (9–1)**CANDIDATE
NAMECENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

CHEMISTRY**0971/41**

Paper 4 Theory (Extended)

May/June 2025**1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

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 and use appropriate units.

INFORMATION

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.

This document has **16** pages. Any blank pages are indicated.





1 A list of substances is shown.

bauxite	calcium oxide	ethanol	graphite	methane
nitrogen	oxygen	propane	propene	sulfur dioxide

Answer the questions using the list of substances.

Each substance may be used once, more than once, or not at all.

State which of the substances:

(a) is a basic oxide

..... [1]

(b) contains carbon atoms only

..... [1]

(c) is manufactured by fermentation

..... [1]

(d) is produced by the decomposition of vegetation

..... [1]

(e) contains aluminium oxide

..... [1]

(f) causes acid rain

..... [1]

(g) is a simple molecule with 11 atoms

..... [1]

(h) is produced when limestone thermally decomposes in the blast furnace

..... [1]

(i) is a gas that is approximately 21% of clean, dry air

..... [1]

(j) is a monomer in addition polymerisation.

..... [1]

[Total: 10]



2 Atoms are made of electrons, neutrons and protons.

(a) Complete Table 2.1.

Table 2.1

particle	relative charge	relative mass
electron		$\frac{1}{1840}$
neutron	0	
proton		

[2]

(b) Atoms of the same element are known as isotopes.

${}_{19}^{39}\text{K}$ and ${}_{19}^{41}\text{K}$ are isotopes of potassium.

(i) Complete Table 2.2 to show the number of electrons, neutrons and protons in one atom or ion of these isotopes.

Table 2.2

isotope	electrons	neutrons	protons
${}_{19}^{39}\text{K}$			
${}_{19}^{41}\text{K}^{+}$			

[3]

(ii) Table 2.3 shows the relative masses and the percentage abundances of the two isotopes in a sample of potassium.

Table 2.3

relative mass of isotope	percentage abundance of isotope
39	90
41	10

Calculate the relative atomic mass of this sample of potassium to **one** decimal place.

relative atomic mass = [2]





(iii) An isotope of aluminium has a nucleon number of 27.

Aluminium has a relative atomic mass of 27.

State what conclusion can be made from this information.

.....
 [1]

(c) A calcium atom has the electronic configuration of 2,8,8,2.

Give the formula of one atom and one negative ion that has the same electronic configuration as Ca^{2+} .

- atom
- negative ion [2]

[Total: 10]



3 This question is about copper and compounds of copper.

(a) (i) Describe the bonding in a metallic element such as copper.

.....

.....

.....

.....

..... [3]

(ii) Explain how solid copper conducts electricity.

..... [1]

(b) Copper is in alloys such as brass.

(i) State **one** reason why alloys are more useful than pure metals.

..... [1]

(ii) Name the substance that is present in brass, other than copper.

..... [1]

(c) Copper(II) sulfate crystals are made by the reaction between copper(II) carbonate and dilute sulfuric acid, using the following steps.

The sulfuric acid has a concentration of 0.100 mol/dm^3 .

step 1 Powdered copper(II) carbonate is added to dilute sulfuric acid. The mixture is stirred. A reaction occurs.

step 2 More copper(II) carbonate is added, with stirring, until the reaction stops.

step 3 Unreacted copper(II) carbonate is separated from aqueous copper(II) sulfate by filtration.

step 4 Aqueous copper(II) sulfate is heated until some of the water evaporates.

step 5 The remaining solution is allowed to cool and crystallise.

step 6 The crystals are removed and dried.

(i) Give **two** observations in **step 1**.

1

2 [2]





(ii) State why the reaction stops in **step 2**.

..... [1]

(iii) Name the residue in **step 3**.

..... [1]

(iv) Name a substance, other than copper(II) carbonate, that can be added to dilute sulfuric acid to produce aqueous copper(II) sulfate.

..... [1]

(v) The solution at the end of **step 4** contains the maximum amount of copper(II) sulfate that will dissolve at that temperature.

State the term used to describe this type of solution.

..... [1]

(vi) **Step 1** is repeated using sulfuric acid of concentration 0.200 mol/dm^3 instead of 0.100 mol/dm^3 .

All other conditions are the same.

The rate of reaction increases.

Explain why the rate of reaction increases. Give your answer in terms of particles.

.....

 [2]

(vii) Copper(II) sulfate crystals have the formula $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

State the term used to describe a substance that is chemically combined with water.

..... [1]

[Total: 15]



- 4 This question is about nitrogen and its compounds.

Nitrogen contains molecules with the formula N_2 .

- (a) Complete the dot-and-cross diagram in Fig. 4.1 to show the electronic configuration in a nitrogen molecule. Show outer-shell electrons only.

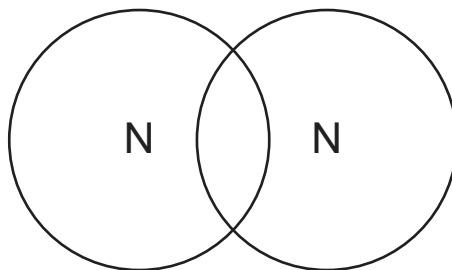


Fig. 4.1

[2]

- (b) Ammonia, NH_3 , is manufactured by reacting nitrogen with hydrogen, H_2 , in the Haber process.

- (i) State **three** typical conditions for the reaction between nitrogen and hydrogen in the Haber process.

- 1
 2
 3 [3]

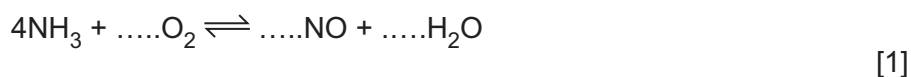
- (ii) Write the symbol equation for the chemical reaction in the Haber process.

..... [1]

- (c) Ammonia is converted into nitric acid in a two-step process.

In step 1, ammonia and oxygen are passed over a catalyst.

- (i) Balance the symbol equation for this reaction.



- (ii) Give the oxidation number of nitrogen in:

- NH_3
- NO

[2]





(iii) Define oxidation in terms of oxidation number.

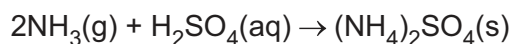
..... [1]

(iv) In step 2, oxygen and water react with NO to produce nitric acid as the only product.

Write a symbol equation for this chemical reaction.

..... [2]

(d) Ammonia is converted into ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$.



360 dm³ of ammonia gas, measured at r.t.p., reacts with excess sulfuric acid.

Calculate the mass of ammonium sulfate produced, using the following steps.

- Calculate the number of moles of $\text{NH}_3(\text{g})$ in 360 dm³.

One mole of any gas occupies 24 dm³ at r.t.p.

..... mol

- Calculate the number of moles of $(\text{NH}_4)_2\text{SO}_4$ produced.

..... mol

- Calculate the mass of $(\text{NH}_4)_2\text{SO}_4$ produced.

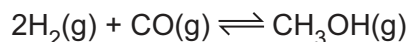
The M_r of $(\text{NH}_4)_2\text{SO}_4$ is 132.

..... g
[3]

[Total: 15]



- 5 Methanol, CH_3OH , is manufactured by the reaction between hydrogen and carbon monoxide. An equilibrium mixture is produced.



- (a) State what happens to the concentration of CH_3OH when the reaction is at equilibrium.

Explain your answer in terms of rate of forward and reverse reactions.

.....

 [2]

- (b) The reaction is carried out at a pressure of 75 atmospheres and a temperature of 250°C .

- (i) State **two** disadvantages of using a pressure **below** 75 atmospheres.

1
 2 [2]

- (ii) Complete Table 5.1 using **only** the words **increases**, **decreases** or **no change**.

Table 5.1

	effect on the concentration of $\text{CH}_3\text{OH}(\text{g})$ at equilibrium	effect on the rate of the reverse reaction
catalyst is added		

[2]

- (iii) If a temperature of more than 250°C is used, the yield of methanol decreases.

State what can be deduced about the forward reaction.

..... [1]

- (iv) Suggest which of the elements from the list is a suitable catalyst for the reaction. Give a reason for your answer.

barium carbon copper potassium sulfur

catalyst

reason

[2]





(c) Methanol is a member of the homologous series of alcohols.

(i) State **two** characteristics of all members of a homologous series.

1

2 [2]

(ii) State the molecular formula of an alcohol that contains five carbon atoms.

..... [1]

(d) Carboxylic acids react with alcohols to form esters.

(i) Draw the displayed formula of an ester which contains three carbon atoms.

[2]

(ii) Butyl ethanoate is an ester.

Name the alcohol and the carboxylic acid that react to produce butyl ethanoate.

alcohol

carboxylic acid [2]

(e) An organic compound has the following composition by mass:

C, 64.87%; H, 13.51%; O, 21.62%.

Calculate the empirical formula of the compound.

empirical formula = [2]

[Total: 18]

[Turn over]





6 This question is about the Periodic Table.

(a) State the name given to Group VII elements.

..... [1]

(b) State which Group VII element is most reactive.

..... [1]

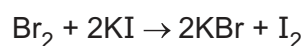
(c) Give the physical state and colour of iodine at room temperature and pressure.

state

colour [2]

(d) When bromine is added to aqueous potassium iodide a displacement reaction occurs.

The equation for the reaction is shown.



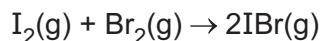
(i) Write an ionic equation for the reaction.

..... [2]



- (ii) Iodine and bromine react at high temperatures to form iodine monobromide, IBr.

The equation is shown.



The structures of the molecules involved in the reaction are I–I, Br–Br and I–Br.

Table 6.1

bond	bond energy in kJ/mol
I–I	150
Br–Br	193
I–Br	175

Calculate the enthalpy change, ΔH , for the reaction using the bond energies in Table 6.1.

Use the following steps.

- Calculate the **total** amount of energy required to break the bonds in 1 mol of $\text{I}_2(\text{g})$ and 1 mol of $\text{Br}_2(\text{g})$.

..... kJ

- Calculate the total amount of energy released when the bonds in 2 mol of IBr(g) are formed.

..... kJ

- Calculate the enthalpy change, ΔH , for the reaction.
Your answer should include a sign.

..... kJ/mol
[3]





(e) Sodium is in Group I of the Periodic Table.

When sodium is added to water a chemical reaction occurs.

(i) Give **two** observations when sodium is added to water.

1

2 [2]

(ii) Thymolphthalein is added to the solution when the reaction has finished.

State the final colour of the thymolphthalein in the solution.

..... [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 Cambridge Assessment. Cambridge Assessment is the brand name of the University of Cambridge Local Examinations Syndicate (UCLES), which is a department of the University of Cambridge.



The Periodic Table of Elements

Group

Group																	
I	II											III	IV	V	VI	VII	VIII