Cambridge Assessment International Education

# Cambridge IGCSE™ (9–1)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CANDIDATE NAME | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | | |

*0352185624*

**CHEMISTRY** **0971/31**

Paper 3 Theory (Core) **May/June 2023**

**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.




**[Turn over**

**1** Fig. 1.1 shows part of the Periodic Table.

| I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | H | | | | | | | | | | He |
| | | | | | | | | | | | | | C | N | O | | |
| Na | Mg | | | | | | | | | | | A*l* | | | | C*l* | |
| K | Ca | | | | | | Fe | | | Cu | | | | | | Br | |
| | | | | | | | | | | | | | | | | I | |

**Fig. 1.1**

Answer the following questions using only the elements in Fig. 1.1.
Each symbol of the element may be used once, more than once or not at all.

Give the symbol of the element that:

**(a)** forms 78% by volume of clean, dry air

..... [1]

**(b)** has an atom with a complete outer electron shell

..... [1]

**(c)** has an atom with five occupied electron shells

..... [1]

**(d)** forms an ion with a charge of 2–

..... [1]

**(e)** forms an ion that gives a green precipitate on addition of aqueous sodium hydroxide

..... [1]

**(f)** is used in food containers because of its resistance to corrosion.

..... [1]

[Total: 6]

**2** **(a)** Table 2.1 shows some properties of the halogens.

**Table 2.1**

| halogen | melting point in °C | boiling point in °C | density at room temperature and pressure in g / cm$^3$ |
|---|---|---|---|
| fluorine | –220 | –188 | 0.0016 |
| chlorine | –101 | –35 | 0.0032 |
| bromine | | +59 | 3.1 |
| iodine | +114 | +184 | |

Use the information in Table 2.1 to predict:

**(i)** the melting point of bromine

..... [1]

**(ii)** the density of iodine at room temperature and pressure

..... [1]

**(iii)** the physical state of chlorine at –10 °C. Give a reason for your answer.

physical state .....

reason .....

.....
[2]

**(b)** The equation for the reaction of aqueous chlorine with aqueous potassium iodide is shown.

$$Cl_2 + 2KI \rightarrow I_2 + 2KCl$$

**(i)** Choose the word which best describes this type of chemical reaction.
Draw a circle around your chosen answer.

**addition** **displacement** **neutralisation** **polymerisation** [1]

**(ii)** Explain why aqueous iodine does **not** react with aqueous potassium chloride.

..... [1]

**(c)** Complete the diagram in Fig. 2.1 to show the electronic configuration of a chlorine atom.

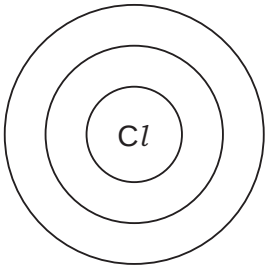


**Fig. 2.1**

[1]

**(d)** Describe a test for chlorine.

test .....

observations .....

[2]

[Total: 9]

**3** **(a)** Water from natural sources contains dissolved gases.

Choose from the list, the gas that is essential for aquatic life.
Draw a circle around your chosen answer.

**argon** **hydrogen** **nitrogen** **oxygen** [1]

**(b)** Polluted water may contain harmful substances such as metal compounds, plastics, nitrates and phosphates.

**(i)** Name one **other** harmful substance which is present in polluted water.

..... [1]

**(ii)** State why nitrates are harmful to aquatic life.

..... [1]

**(c)** Table 3.1 shows the masses of ions, in mg, present in a 1000 $cm^3$ sample of polluted water.

**Table 3.1**

| name of ion | formula of ion | mass of ion present in mg / 1000 $cm^3$ of polluted water |
|---|---|---|
| | $NH_4^+$ | 0.5 |
| calcium | $Ca^{2+}$ | 2.2 |
| chloride | $Cl^-$ | 2.5 |
| hydrogencarbonate | $HCO_3^-$ | 12.0 |
| magnesium | $Mg^{2+}$ | 0.8 |
| nitrate | $NO_3^-$ | 0.4 |
| potassium | $K^+$ | 8.3 |
| silicate | $SiO_3^{2-}$ | 8.0 |
| sodium | $Na^+$ | 10.2 |
| sulfate | $SO_4^{2-}$ | 0.2 |
| tin(II) | $Sn^{2+}$ | 0.4 |

Answer these questions using information from Table 3.1.

**(i)** Name the negative ion present in the highest concentration.

..... [1]

**(ii)** State the name of the $NH_4^+$ ion.

..... [1]

**(iii)** Calculate the mass of calcium ions present in 200 $cm^3$ of polluted water.

mass = ..... mg [1]

**(d)** Copper(II) sulfate can be used to test for the presence of water.

$$CuSO_4(s) + 5H_2O(l) \rightleftharpoons CuSO_4 \bullet 5H_2O(s)$$

anhydrous copper(II) sulfate — hydrated copper(II) sulfate

**(i)** State the meaning of the term hydrated.

..... [1]

**(ii)** Describe how hydrated copper(II) sulfate is changed to anhydrous copper(II) sulfate.

..... [1]

**(e)** Complete the symbol equation for the reaction of sodium with water.

$$2Na + .....H_2O \rightarrow 2NaOH + .....$$ [2]

[Total: 10]

**4** This question is about sulfur and compounds of sulfur.

**(a)** Sulfur has several isotopes.

Define the term isotopes.

.....

..... [2]

**(b)** Deduce the number of protons, neutrons and electrons in the sulfide ion shown.

$^{36}_{16}S^{2-}$

number of protons .....

number of neutrons .....

number of electrons .....
[3]

**(c)** Sulfur burns in oxygen to produce sulfur dioxide.

Fig. 4.1 shows an incomplete reaction pathway diagram for this reaction.

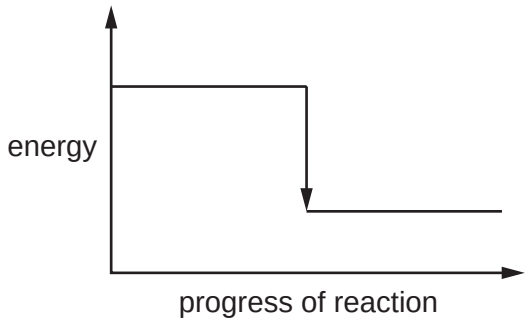


**Fig. 4.1**

**(i)** Complete Fig. 4.1 by writing these formulae on the diagram:
- $S + O_2$
- $SO_2$. [1]

**(ii)** Explain how Fig. 4.1 shows that the reaction is exothermic.

.....

..... [1]

**(iii)** Complete this sentence about an exothermic reaction using a word from the list.

**products** **reactants** **sulfur** **surroundings**

An exothermic reaction transfers thermal energy to the ..... . [1]

**(d)** Fig. 4.2 shows the apparatus used for the electrolysis of dilute sulfuric acid using graphite electrodes.

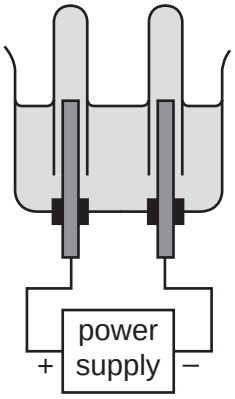


**Fig. 4.2**

**(i)** Label Fig. 4.2 to show:
- the cathode
- the electrolyte. [2]

**(ii)** Name the products and state the observations at the positive and negative electrodes.

product at the positive electrode

.....

observations at the positive electrode

.....

product at the negative electrode

.....

observations at the negative electrode

.....
[4]

**(e)** Complete the word equation for the reaction of dilute sulfuric acid with sodium carbonate.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| sulfuric acid | + | sodium carbonate | → | ..... ..... | + | ..... ..... | + | ..... |

[3]

**(f)** A few drops of thymolphthalein indicator are added to dilute sulfuric acid.

State the colour of the solution.

..... [1]

[Total: 18]

**5** This question is about metals.

**(a)** Iron is a transition element. Potassium is an element in Group I of the Periodic Table.

State **two** differences in the physical properties of iron compared to potassium.

1 .....

2 .....
[2]

**(b)** Carbon is used to extract iron from iron ore in a blast furnace.

State **two** uses of carbon in the extraction process.

1 .....

2 .....
[2]

**(c)** Steel is an alloy of iron.

**(i)** State the meaning of the term alloy.

.....

..... [1]

**(ii)** State why alloys are more useful than pure metals.

..... [1]

**(d)** Table 5.1 shows the observations made when four different metals react with dilute hydrochloric acid of the same concentration.

**Table 5.1**

| metal | observations |
|---|---|
| iron | bubbles form slowly |
| lead | no bubbles formed |
| magnesium | bubbles form rapidly |
| nickel | bubbles form very slowly |

Put the four metals in order of their reactivity.
Put the least reactive metal first.

least reactive ⟶ most reactive

| | | | |
|---|---|---|---|
| | | | |

[2]

[Total: 8]

**6** **(a)** A student investigates the reaction of small pieces of zinc of the same mass and size with three different concentrations of dilute hydrochloric acid in the presence of a catalyst.

The three concentrations of dilute hydrochloric acid are:

- 1.0 mol / $dm^3$
- 1.5 mol / $dm^3$
- 2.0 mol / $dm^3$.

All other conditions stay the same.

Table 6.1 shows the time taken for each reaction to finish.

**Table 6.1**

| concentration of hydrochloric acid in mol / $dm^3$ | time taken for the reaction to finish in s |
|---|---|
| | 200 |
| | 100 |
| | 150 |

**(i)** Complete Table 6.1 by writing the concentrations of hydrochloric acid in the first column. [1]

**(ii)** Describe the effect on the time taken for the zinc to finish reacting with 2.0 mol / $dm^3$ hydrochloric acid with no catalyst present.

All other conditions stay the same.

..... [1]

**(iii)** Describe the effect on the time taken for the zinc to finish reacting with 2.0 mol / $dm^3$ hydrochloric acid when the surface area of the zinc is increased.

All other conditions stay the same.

..... [1]

**(b)** Crystals of zinc chloride can be prepared by reacting excess zinc with dilute hydrochloric acid.

Choose from the list, the method used to separate the unreacted zinc from the reaction mixture.

Draw a circle around your chosen answer.

**chromatography** **crystallisation** **evaporation** **filtration** [1]

**(c)** Zinc chloride is soluble in water.

Choose one **other** compound that is soluble in water.

Tick (✓) **one** box.

| | |
|---|---|
| calcium carbonate | ☐ |
| lead(II) chloride | ☐ |
| silver chloride | ☐ |
| sodium nitrate | ☐ |

[1]

[Total: 5]

**7** **(a)** Fig. 7.1 shows the displayed formula of mesaconic acid.

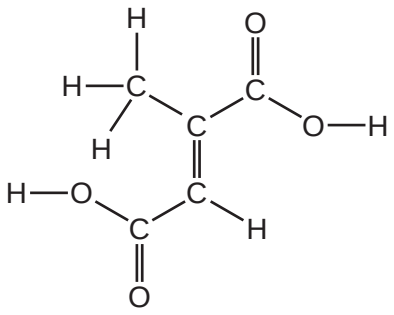

**Fig. 7.1**

**(i)** On Fig. 7.1 draw a circle around **one** carboxylic acid functional group. [1]

**(ii)** Deduce the molecular formula of mesaconic acid.

..... [1]

**(iii)** Mesaconic acid is a colourless compound.

Describe the colour change when excess mesaconic acid is added to aqueous bromine.

from ..... to ..... [2]

**(b)** Ethanoic acid belongs to the homologous series of carboxylic acids.

Define the term homologous series.

.....

..... [2]

**(c)** Complete the word equation for the reaction of ethanoic acid with magnesium.

| ethanoic acid | + | magnesium | → | ..... ..... | + | ..... |
|---|---|---|---|---|---|---|

[2]

**(d)** Ethanoic acid reacts with ethanol.
The organic product has the molecular formula $C_4H_8O_2$.

Complete Table 7.1 to calculate the relative molecular mass of $C_4H_8O_2$.

**Table 7.1**

| atom | number of atoms | relative atomic mass | |
|---|---|---|---|
| carbon | 4 | 12 | $4 \times 12 = 48$ |
| hydrogen | | 1 | |
| oxygen | | 16 | |

relative molecular mass = ..... [2]

**(e)** Ethanol can be manufactured by fermentation.

Complete the word equation for one **other** method of manufacturing ethanol.

..... + ..... → ethanol [2]

[Total: 12]

**8** This question is about nitrogen and compounds of nitrogen.

**(a)** Nitrogen is a non-metal. Nitrogen is a poor electrical conductor.

Describe two **other** physical properties which are typical of non-metals.

1 .....

2 .....

[2]

**(b)** Oxides of nitrogen are air pollutants which contribute to acid rain.

**(i)** State **one** source of oxides of nitrogen in the air.

..... [1]

**(ii)** State one **other** adverse effect of oxides of nitrogen.

..... [1]

**(c)** Ammonia is a simple molecule with covalent bonds.

**(i)** Describe a covalent bond.

.....

..... [2]

**(ii)** Complete Fig. 8.1 to show the dot-and-cross diagram for a molecule of ammonia.

Show outer shell electrons only.

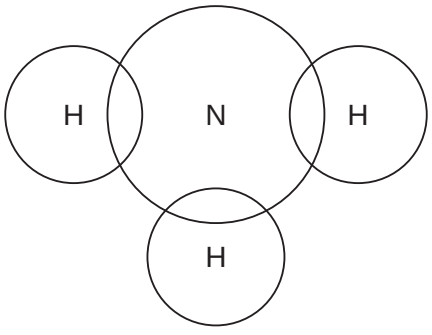


**Fig. 8.1**

[2]

**(iii)** Aqueous ammonia is alkaline.

Choose from the list, the pH value that is alkaline.

Draw a circle around your chosen answer.

**pH 1** **pH 5** **pH 7** **pH 10** [1]

**(iv)** Aqueous ammonia releases ammonia gas.

Ammonia gas turns damp red litmus paper blue.

A long glass tube is set up as shown in Fig. 8.2.

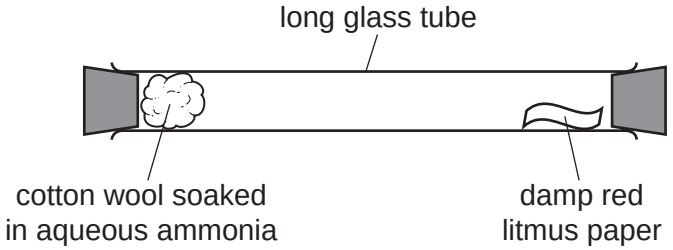


**Fig. 8.2**

At first, the litmus paper does **not** turn blue.
After a short time, the litmus paper turns blue.

Explain these results in terms of the kinetic particle theory.

.....

.....

.....

.....

..... [3]

[Total: 12]

## The Periodic Table of Elements

| Group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
| | | | | | | | 1 H hydrogen 1 | | | | | | | | | | 2 He helium 4 |
| 3 Li lithium 7 | 4 Be beryllium 9 | | | | | | | | | | | 5 B boron 11 | 6 C carbon 12 | 7 N nitrogen 14 | 8 O oxygen 16 | 9 F fluorine 19 | 10 Ne neon 20 |
| 11 Na sodium 23 | 12 Mg magnesium 24 | | | | | | | | | | | 13 Al aluminium 27 | 14 Si silicon 28 | 15 P phosphorus 31 | 16 S sulfur 32 | 17 Cl chlorine 35.5 | 18 Ar argon 40 |
| 19 K potassium 39 | 20 Ca calcium 40 | 21 Sc scandium 45 | 22 Ti titanium 48 | 23 V vanadium 51 | 24 Cr chromium 52 | 25 Mn manganese 55 | 26 Fe iron 56 | 27 Co cobalt 59 | 28 Ni nickel 59 | 29 Cu copper 64 | 30 Zn zinc 65 | 31 Ga gallium 70 | 32 Ge germanium 73 | 33 As arsenic 75 | 34 Se selenium 79 | 35 Br bromine 80 | 36 Kr krypton 84 |
| 37 Rb rubidium 85 | 38 Sr strontium 88 | 39 Y yttrium 89 | 40 Zr zirconium 91 | 41 Nb niobium 93 | 42 Mo molybdenum 96 | 43 Tc technetium – | 44 Ru ruthenium 101 | 45 Rh rhodium 103 | 46 Pd palladium 106 | 47 Ag silver 108 | 48 Cd cadmium 112 | 49 In indium 115 | 50 Sn tin 119 | 51 Sb antimony 122 | 52 Te tellurium 128 | 53 I iodine 127 | 54 Xe xenon 131 |
| 55 Cs caesium 133 | 56 Ba barium 137 | 57–71 lanthanoids | 72 Hf hafnium 178 | 73 Ta tantalum 181 | 74 W tungsten 184 | 75 Re rhenium 186 | 76 Os osmium 190 | 77 Ir iridium 192 | 78 Pt platinum 195 | 79 Au gold 197 | 80 Hg mercury 201 | 81 Tl thallium 204 | 82 Pb lead 207 | 83 Bi bismuth 209 | 84 Po polonium – | 85 At astatine – | 86 Rn radon – |
| 87 Fr francium – | 88 Ra radium – | 89–103 actinoids | 104 Rf rutherfordium – | 105 Db dubnium – | 106 Sg seaborgium – | 107 Bh bohrium – | 108 Hs hassium – | 109 Mt meitnerium – | 110 Ds darmstadtium – | 111 Rg roentgenium – | 112 Cn copernicium – | 113 Nh nihonium – | 114 Fl flerovium – | 115 Mc moscovium – | 116 Lv livermorium – | 117 Ts tennessine – | 118 Og oganesson – |

**Key**

atomic number
atomic symbol
name
relative atomic mass

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lanthanoids | 57 La lanthanum 139 | 58 Ce cerium 140 | 59 Pr praseodymium 141 | 60 Nd neodymium 144 | 61 Pm promethium – | 62 Sm samarium 150 | 63 Eu europium 152 | 64 Gd gadolinium 157 | 65 Tb terbium 159 | 66 Dy dysprosium 163 | 67 Ho holmium 165 | 68 Er erbium 167 | 69 Tm thulium 169 | 70 Yb ytterbium 173 | 71 Lu lutetium 175 |
| actinoids | 89 Ac actinium – | 90 Th thorium 232 | 91 Pa protactinium 231 | 92 U uranium 238 | 93 Np neptunium – | 94 Pu plutonium – | 95 Am americium – | 96 Cm curium – | 97 Bk berkelium – | 98 Cf californium – | 99 Es einsteinium – | 100 Fm fermium – | 101 Md mendelevium – | 102 No nobelium – | 103 Lr lawrencium – |

The volume of one mole of any gas is 24 $dm^3$ at room temperature and pressure (r.t.p.).