Cambridge Assessment International Education

# Cambridge IGCSE™ (9–1)

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

*6916921236*

**CHEMISTRY** **0971/41**

Paper 4 Theory (Extended) **May/June 2020**

**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 **12** pages. Blank pages are indicated.

**1** This question is about elements **X**, **Y** and **Z**.

**(a)** An atom of element **X** is represented as $^{34}_{16}\mathbf{X}$.

**(i)** Name the different types of particles found in the nucleus of this atom of **X**.

.....

..... [2]

**(ii)** What is the term for the total number of particles in the nucleus of an atom?

..... [1]

**(iii)** What is the total number of particles in the nucleus of an atom of $^{34}_{16}\mathbf{X}$?

..... [1]

**(iv)** What is the electronic structure of the ion $\mathbf{X}^{2-}$?

..... [1]

**(v)** Suggest the formula of the compound formed between aluminium and **X**.

..... [1]

**(b) (i)** What term is used to describe atoms of the same element with different numbers of particles in the nucleus?

..... [1]

**(ii)** Identify the atom against which the relative masses of all other atoms are compared.

..... [1]

**(iii)** What is the name of the amount of any substance that contains $6.02 \times 10^{23}$ particles?

..... [1]

**(iv)** The constant $6.02 \times 10^{23}$ has a name.

What is the name of this constant?

..... [1]

**(c)** Part of the definition of relative atomic mass is 'the average mass of naturally occurring atoms of an element'.

Some relative atomic masses are not whole numbers.

Element **Y** has only two different types of atom, $^{69}$**Y** and $^{71}$**Y**.

The ratio of atoms present in element **Y** is shown.

$$^{69}\mathbf{Y} : {}^{71}\mathbf{Y} = 3 : 2$$

- Calculate the relative atomic mass of element **Y** to **one decimal place**.

relative atomic mass = .....

- Identify element **Y**.

.....
[3]

**(d)** Element **Z** is in Period 3 and Group V.

**(i)** Identify element **Z**.

..... [1]

**(ii)** Explain in terms of electron transfer why **Z** behaves chemically as a non-metal.

.....

..... [2]

[Total: 16]



**[Turn over**

**2** Magnesium is a metal.

**(a)** Name and describe the bonding in magnesium.

name .....

description of bonding .....

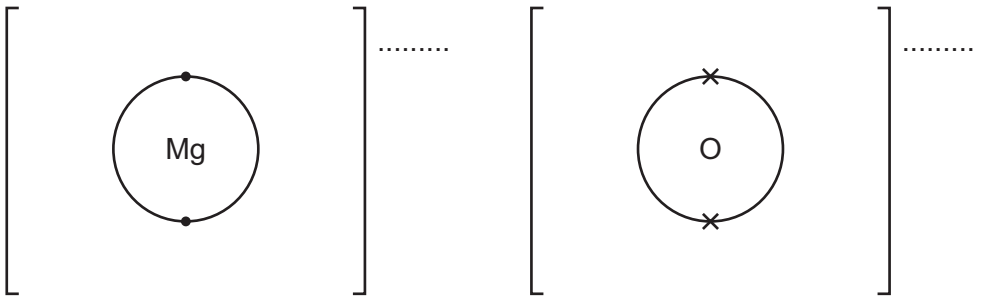
.....

.....

[4]

**(b)** Magnesium oxide, MgO, is formed when magnesium burns in oxygen.

**(i)** Complete the dot-and-cross diagram to show the electron arrangement of the ions in magnesium oxide.
The inner shells have been drawn.
Give the charges on the ions.




[3]

**(ii)** Write the chemical equation for the reaction that occurs when magnesium burns in oxygen.

..... [2]

**(c)** Magnesium oxide also forms when magnesium nitrate, $Mg(NO_3)_2$, is heated strongly. This is an endothermic reaction.

**(i)** Write the chemical equation for this reaction.

..... [2]

**(ii)** What type of reaction is this?

..... [1]

**(iii)** Name **two** other compounds of magnesium that form magnesium oxide when heated.

.....

..... [2]

[Total: 14]

**3** Sulfur dioxide, $SO_2$, is used in the manufacture of sulfuric acid.

**(a)** In the first stage of the process, sulfur dioxide is obtained from sulfur-containing ores.

Name **one** of these ores.

..... [1]

**(b)** The next stage of the process is a reaction which can reach equilibrium.

The equation for this stage is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

**(i)** Describe **two** features of an equilibrium.

.....

..... [2]

**(ii)** Name the catalyst used in this stage.

..... [1]

**(iii)** Why is a catalyst used?

..... [1]

**(iv)** Explain, in terms of particles, why a high temperature increases the rate of this reaction.

.....

.....

.....

.....

..... [3]

**(v)** In this stage, only a moderate temperature of 450 °C is used.

What does this suggest about the forward reaction?

..... [1]

**(vi)** Calculate the percentage by mass of sulfur in sulfur trioxide, $SO_3$.

percentage = ..... [2]



**[Turn over**

**(c)** Concentrated sulfuric acid is a dehydrating agent which can chemically remove water from substances.

Both hydrated copper(II) sulfate crystals and sucrose (a sugar), $C_{12}H_{22}O_{11}$, can be completely dehydrated by concentrated sulfuric acid.

Name the solid product formed in each case.

hydrated copper(II) sulfate crystals .....

sucrose .....
[2]

**(d)** When propan-1-ol is heated with concentrated sulfuric acid as a catalyst an unsaturated hydrocarbon of relative molecular mass 42 is formed and one other product.

**(i)** What is meant by the term *unsaturated*?

..... [1]

**(ii)** Write the chemical equation for this reaction.

..... [2]

**(iii)** Name the unsaturated hydrocarbon formed.

..... [1]

[Total: 17]

**4** This question is about reactions of bases and acids.

**(a)** Ammonia is a gas at room temperature.

What is the test for ammonia gas? Describe the positive result of this test.

test .....

result .....
[2]

**(b)** Ammonia reacts with water to form ions.

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

**(i)** How does this equation show that ammonia, $NH_3$, behaves as a base?

..... [1]

**(ii)** Aqueous ammonia is described as a weak base.

Suggest the pH of aqueous ammonia.

pH = ..... [1]

**(iii)** Describe what is seen when aqueous ammonia is added to aqueous copper(II) sulfate, until no further change is seen.

.....

.....

..... [3]

**(c)** Aqueous sodium hydroxide, NaOH(aq), is a strong alkali that reacts with dilute sulfuric acid exothermically.

**(i)** What type of reaction is this?

..... [1]

**(ii)** Complete the equation for the reaction between aqueous sodium hydroxide and dilute sulfuric acid.

$2NaOH + H_2SO_4 \rightarrow$ ..... + .....

[2]

**(d)** A student wanted to find the concentration of some dilute sulfuric acid by titration. The student found that 25.0 $cm^3$ of 0.0400 $mol/dm^3$ NaOH(aq) reacted exactly with 20.0 $cm^3$ of $H_2SO_4$(aq).

**(i)** Name a suitable indicator to use in this titration.

..... [1]

**(ii)** Calculate the concentration of the $H_2SO_4$(aq) in $mol/dm^3$ using the following steps.

- Calculate the number of moles of NaOH in 25.0 $cm^3$.

moles = .....

- Deduce the number of moles of $H_2SO_4$ that reacted with the 25.0 $cm^3$ of NaOH(aq).

moles = .....

- Calculate the concentration of $H_2SO_4$(aq) in $mol/dm^3$.

concentration = ..... $mol/dm^3$

[3]

**(iii)** Calculate the concentration of the 0.0400 $mol/dm^3$ NaOH(aq) in $g/dm^3$.

concentration = ..... $g/dm^3$ [2]

[Total: 16]

**5** Ethanol is manufactured by two different processes.

**(a)** For each process, name the organic reactant and state the type of reaction.

organic reactant ..... type of reaction .....

organic reactant ..... type of reaction .....

[4]

**(b)** Alcohols can be oxidised to form carboxylic acids.

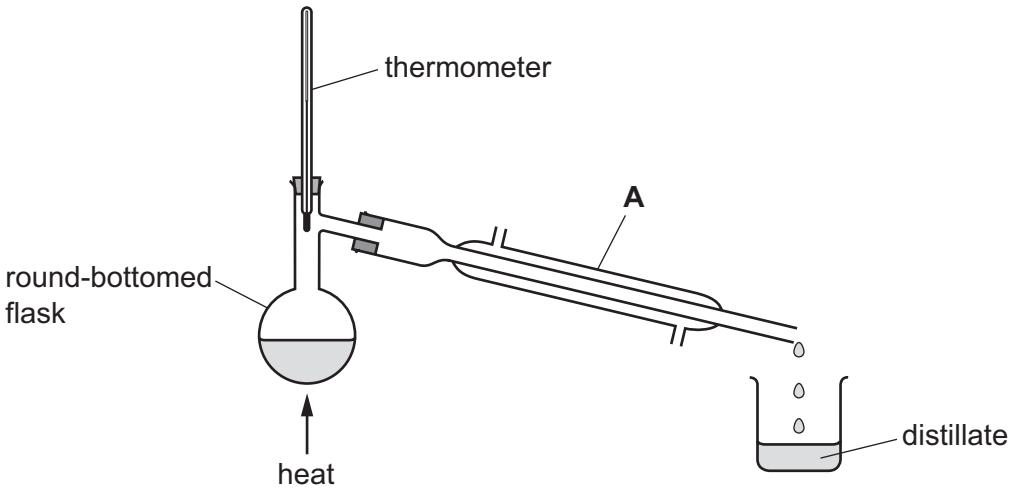
Name a suitable oxidising agent for this reaction.

..... [1]

**(c)** Alcohols can be partially oxidised to form aldehydes.

Aldehydes are a homologous series of organic compounds.

Partial oxidation is achieved by reacting an alcohol with the oxidising agent in distillation apparatus as shown.




**(i)** Name apparatus **A**.

..... [1]

**(ii)** On the diagram, use **one** arrow to show where water enters apparatus **A**. [1]

**(d)** The table shows some information about aldehydes.

**(i)** Complete the table.

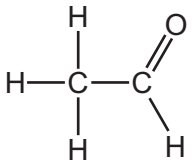
| name | ..... | ethanal | propanal | butanal |
|---|---|---|---|---|
| molecular formula | $CH_2O$ | $C_2H_4O$ | $C_3H_6O$ | ..... |

[2]

**(ii)** Deduce the general formula of aldehydes.

..... [1]

**(e)** The structural formula of ethanal is shown.

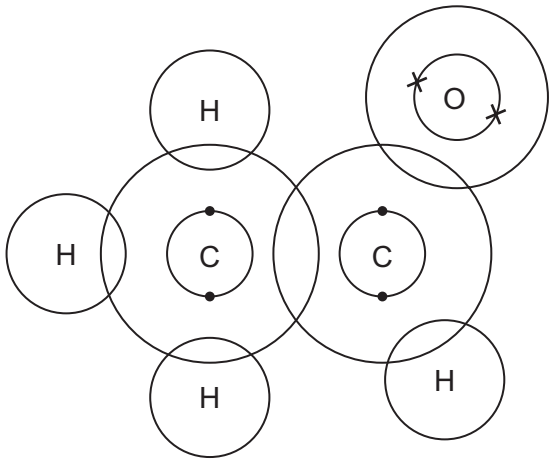



The C=O group in aldehydes is at the end of the carbon chain.
This is a reactive part of the molecule.

**(i)** What is the name given to the reactive part of any organic molecule?

..... [1]

**(ii)** Complete the dot-and-cross diagram to show the electron arrangement of a molecule of ethanal. Inner shells have been drawn.




[3]

**(f)** Propanone belongs to a homologous series called ketones. Ketones have the same C=O group as aldehydes but the C=O group is not at the end of the carbon chain. Propanone has the same molecular formula as propanal, $C_3H_6O$.

**(i)** What term is used to describe molecules with different structures but with the same molecular formula?

..... [1]

**(ii)** Suggest the structure of propanone, $C_3H_6O$. Show all of the atoms and all of the bonds.

[2]

[Total: 17]

## 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 – | | 114 Fl flerovium – | | 116 Lv livermorium – | | |

**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.).