



# Cambridge IGCSE™ (9–1)

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## CHEMISTRY

0971/41

Paper 4 Theory (Extended)

May/June 2023

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

## INSTRUCTIONS

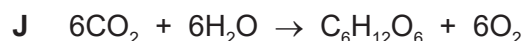
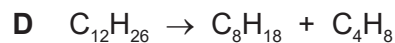
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction 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. Any blank pages are indicated.

1 Some symbol equations and word equations, **A** to **J**, are shown.



Use the equations to answer the questions that follow.

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

Give the letter, **A** to **J**, for the equation that represents:

(a) a neutralisation reaction ..... [1]

(b) a precipitation reaction ..... [1]

(c) the formation of an ester ..... [1]

(d) photosynthesis ..... [1]

(e) fermentation ..... [1]

(f) cracking. .... [1]

[Total: 6]

2 (a) The symbols of the elements in Period 2 of the Periodic Table are shown.

Li Be B C N O F Ne

Use the symbols of the elements in Period 2 to answer the questions that follow.  
Each symbol may be used once, more than once or not at all.

Give the symbol of the element that:

- (i) makes up approximately 78% of clean, dry air ..... [1]
- (ii) contains atoms with only three electrons in the outer shell ..... [1]
- (iii) contains atoms with only nine protons ..... [1]
- (iv) exists as graphite ..... [1]
- (v) is an alkali metal ..... [1]
- (vi) **only** has an oxidation number of zero. .... [1]

(b) Boron, B, has two isotopes.

- (i) State the meaning of the term isotopes.

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

- (ii) Table 2.1 shows the relative masses and the percentage abundances of the two isotopes of boron.

**Table 2.1**

| relative mass of isotope | percentage abundance of isotope |
|--------------------------|---------------------------------|
| 10                       | 20                              |
| 11                       | 80                              |

Calculate the relative atomic mass of boron to **one** decimal place.

relative atomic mass = ..... [2]

[Total: 10]

3 This question is about ionic and covalent compounds.

- (a) (i) Sodium reacts with oxygen to form the ionic compound sodium oxide.  
The electronic configurations of an atom of sodium and an atom of oxygen are shown in Fig. 3.1.



Fig. 3.1

Ions are formed by the transfer of electrons from sodium atoms to oxygen atoms.

Complete the dot-and-cross diagrams in Fig. 3.2 to show the electronic configuration of **one** sodium ion and **one** oxide ion. Show the charges on the ions.

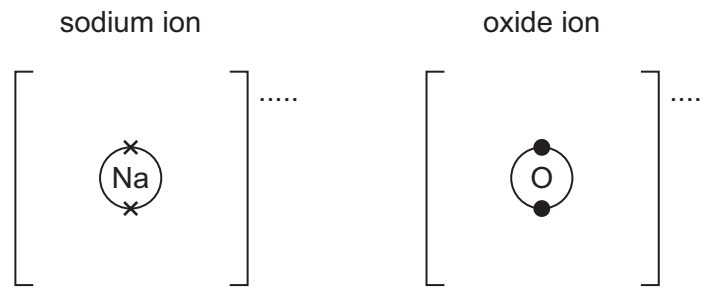


Fig. 3.2

[3]

- (ii) Write the formula of sodium oxide.

..... [1]

- (b) Carbon dioxide,  $\text{CO}_2$ , is a covalent compound.

Complete the dot-and-cross diagram in Fig. 3.3 to show the electronic configuration in a molecule of carbon dioxide. Show outer shell electrons only.

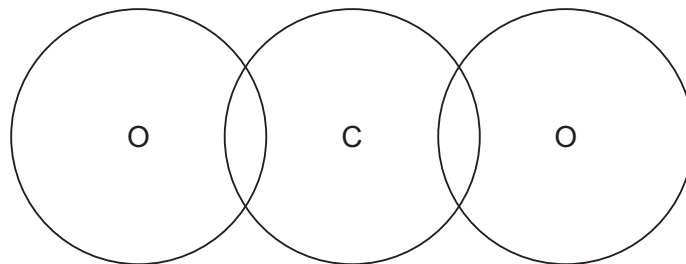


Fig. 3.3

[2]

(c) The melting points of sodium oxide and carbon dioxide are shown in Table 3.1.

**Table 3.1**

|                | melting point/°C |
|----------------|------------------|
| sodium oxide   | 1275             |
| carbon dioxide | -78              |

(i) Explain, in terms of bonding, why sodium oxide has a high melting point.

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

(ii) Carbon dioxide has a low melting point.

State the general term for the weak forces that cause carbon dioxide to have a low melting point.

..... [1]

[Total: 9]

- 4 Oxygen is produced by the decomposition of aqueous hydrogen peroxide. Manganese(IV) oxide,  $\text{MnO}_2$ , is a catalyst for this reaction.

(a) State the meaning of the term catalyst.

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

- (b) A student adds powdered manganese(IV) oxide to aqueous hydrogen peroxide in a conical flask as shown in Fig. 4.1. The mass of the conical flask and its contents is measured at regular time intervals. The mass decreases as time increases.

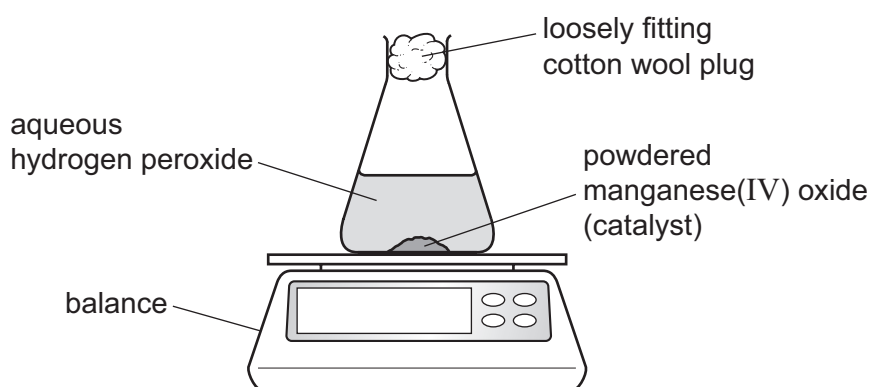


Fig. 4.1

- (i) State why the mass of the conical flask and its contents decreases as time increases.

..... [1]

- (ii) The rate of reaction is highest at the start of the reaction. The rate decreases and eventually becomes zero.

Explain why the rate of reaction is highest at the start of the reaction.

.....  
 ..... [1]

- (iii) Explain why the rate of reaction eventually becomes zero.

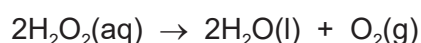
.....  
 ..... [1]

- (c) The experiment is repeated at an increased temperature.  
All other conditions stay the same.

Explain in terms of collision theory why the rate of reaction is higher at an increased temperature.

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

- (d) The equation for the decomposition of aqueous hydrogen peroxide,  $\text{H}_2\text{O}_2(\text{aq})$ , is shown.



50.0 cm<sup>3</sup> of a 0.200 mol/dm<sup>3</sup> solution of  $\text{H}_2\text{O}_2(\text{aq})$  is used.

Calculate the mass of  $\text{O}_2$  that forms.  
Use the following steps.

- Calculate the number of moles of  $\text{H}_2\text{O}_2$  used.

..... mol

- Determine the number of moles of  $\text{O}_2$  produced.

..... mol

- Calculate the mass of  $\text{O}_2$  produced.

..... g  
[3]

- (e) State the effect on the mass of oxygen produced if the mass of powdered manganese(IV) oxide catalyst is increased.

..... [1]

- (f) Oxygen can also be produced by the decomposition of mercury(II) oxide,  $\text{HgO}$ .  
The only products of this decomposition are mercury and oxygen.

Write a symbol equation for this decomposition.

..... [2]

[Total: 14]

5 This question is about electricity and chemical reactions.

- (a) The electrolysis of concentrated aqueous potassium bromide using graphite electrodes forms:
- hydrogen at the cathode
  - bromine at the anode.

The electrolyte becomes aqueous potassium hydroxide.

- (i) State what is meant by the term electrolysis.

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

- (ii) State why graphite is suitable for use as an electrode.

..... [1]

- (iii) Write an ionic half-equation for the formation of hydrogen at the cathode.

..... [2]

- (iv) Name the type of particle responsible for the transfer of charge in the conducting wires.

..... [1]

- (v) Name the type of particle responsible for the transfer of charge in aqueous potassium bromide.

..... [1]

- (vi) State the names of the products formed when electricity is passed through **dilute** aqueous potassium bromide using graphite electrodes.

at the anode .....

at the cathode.....

[2]

- (b) Bauxite is an ore containing aluminium.

Aluminium is extracted by electrolysis of purified bauxite in molten cryolite using carbon electrodes.

- (i) Name the aluminium compound in purified bauxite.

..... [1]

- (ii) State **two** reasons why cryolite is used in this electrolysis.

1 .....

2 .....

[2]



(iii) The anode is made from carbon.

Explain why the carbon anode has to be replaced regularly.

.....  
..... [1]

(c) Hydrogen–oxygen fuel cells can be used to produce electricity in vehicles.

(i) Write the symbol equation for the overall reaction in a hydrogen–oxygen fuel cell.

..... [2]

(ii) State **one** advantage of using hydrogen–oxygen fuel cells instead of petrol in vehicle engines.

..... [1]

[Total: 16]

- 6 This question is about sulfur and compounds of sulfur.

Sulfur is converted into sulfuric acid,  $\text{H}_2\text{SO}_4$ , by the Contact process.

The process involves four stages.

**stage 1** Molten sulfur is converted into sulfur dioxide.

**stage 2** Sulfur dioxide reacts with oxygen to form sulfur trioxide.

**stage 3** Sulfur trioxide combines with concentrated sulfuric acid to form oleum,  $\text{H}_2\text{S}_2\text{O}_7$ .

**stage 4** Oleum reacts to form concentrated sulfuric acid.

- (a) (i) In **stage 1**, iron pyrites,  $\text{FeS}_2$ , can be used instead of molten sulfur.  
The iron pyrites is heated strongly in air.

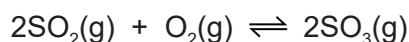
Balance the equation for the reaction occurring when iron pyrites reacts with oxygen in the air.



- (ii) Name  $\text{Fe}_2\text{O}_3$ . Include the oxidation number of iron.

..... [1]

- (b) The equation for **stage 2** is shown.



The forward reaction is exothermic.

The reaction is carried out at a temperature of  $450^\circ\text{C}$  and a pressure of 2 atm.

Using explanations that do **not** involve cost:

- (i) explain why a temperature greater than  $450^\circ\text{C}$  is **not** used

..... [1]

- (ii) explain why a pressure lower than 2 atm is **not** used.

..... [1]

- (c) When sulfuric acid reacts with ammonia the salt produced is ammonium sulfate.

Write the symbol equation for this reaction.

..... [2]

**(d)** Lead(II) sulfate is an insoluble salt.

Lead(II) sulfate can be made from aqueous ammonium sulfate using a precipitation reaction.

**(i)** Name a solution that can be added to aqueous ammonium sulfate to produce a precipitate of lead(II) sulfate.

..... [1]

**(ii)** Write an ionic equation for this precipitation reaction. Include state symbols.

..... [3]

**(iii)** The precipitate of lead(II) sulfate forms in an aqueous solution.

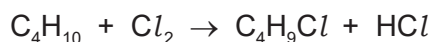
Describe how pure lead(II) sulfate can be obtained from the mixture.

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

[Total: 13]

7 This question is about organic compounds.

(a) Butane reacts with chlorine in a photochemical reaction.



(i) State the meaning of the term photochemical.

..... [1]

(ii) An organic compound with the formula  $\text{C}_4\text{H}_9\text{Cl}$  is formed when one molecule of butane reacts with one molecule of chlorine.

Draw the displayed formulae of **two** possible structural isomers with the formula  $\text{C}_4\text{H}_9\text{Cl}$  formed in this reaction.

[2]

(b) The structure of compound **A** is shown in Fig. 7.1.

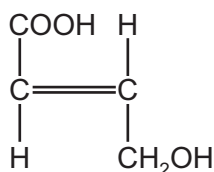


Fig. 7.1

(i) Deduce the molecular formula of compound **A**.

..... [1]

(ii) There are three functional groups in compound **A**.

Name the homologous series of compounds that contain the following functional groups:

$-\text{C}=\text{C}-$  .....

$-\text{OH}$  .....

$-\text{COOH}$ . .....

[3]

(iii) State what is observed when compound **A** is added to:

aqueous bromine .....

aqueous sodium carbonate. ....

[2]

(iv) Compound **A** can be used as a single monomer to produce two different polymers.

Draw **one** repeat unit of the addition polymer formed from compound **A**.

[2]

(v) Compound **A** can be converted into a dicarboxylic acid.

Name the type of condensation polymer formed from a dicarboxylic acid and a diol.

..... [1]

[Total: 12]



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## The Periodic Table of Elements

|                      |                       | Group               |                       |                       |                        |                        |                       |                      |                       |                      |                     |                      |                      |                       |                        |                       |                    |                      |                     |                        |                            |                       |                         |                      |                      |                         |                           |                          |                          |                       |                        |                        |                          |                         |                       |
|----------------------|-----------------------|---------------------|-----------------------|-----------------------|------------------------|------------------------|-----------------------|----------------------|-----------------------|----------------------|---------------------|----------------------|----------------------|-----------------------|------------------------|-----------------------|--------------------|----------------------|---------------------|------------------------|----------------------------|-----------------------|-------------------------|----------------------|----------------------|-------------------------|---------------------------|--------------------------|--------------------------|-----------------------|------------------------|------------------------|--------------------------|-------------------------|-----------------------|
| I                    | II                    | III                 | IV                    | V                     | VI                     | VII                    | VIII                  |                      |                       |                      |                     |                      |                      |                       |                        |                       |                    |                      |                     |                        |                            |                       |                         |                      |                      |                         |                           |                          |                          |                       |                        |                        |                          |                         |                       |
| 1                    | 2                     | 3                   | 4                     | 5                     | 6                      | 7                      | 8                     | 9                    | 10                    | 11                   | 12                  | 13                   | 14                   | 15                    | 16                     | 17                    | 18                 |                      |                     |                        |                            |                       |                         |                      |                      |                         |                           |                          |                          |                       |                        |                        |                          |                         |                       |
| Li<br>lithium<br>7   | Be<br>beryllium<br>9  | B<br>boron<br>11    | C<br>carbon<br>12     | Al<br>aluminium<br>13 | Si<br>silicon<br>14    | P<br>phosphorus<br>15  | S<br>sulfur<br>16     | Cl<br>chlorine<br>17 | Ar<br>argon<br>18     | K<br>potassium<br>19 | Ca<br>calcium<br>20 | Sc<br>scandium<br>21 | Ti<br>titanium<br>22 | V<br>vanadium<br>23   | Cr<br>chromium<br>24   | Mn<br>manganese<br>25 | Fe<br>iron<br>26   | Co<br>cobalt<br>27   | Ni<br>nickel<br>28  | Cu<br>copper<br>29     | Zn<br>zinc<br>30           | Ga<br>gallium<br>31   | Ge<br>germanium<br>32   | As<br>arsenic<br>33  | Se<br>selenium<br>34 | Br<br>bromine<br>35     | Kr<br>krypton<br>36       |                          |                          |                       |                        |                        |                          |                         |                       |
| 37                   | 38                    | 39                  | 40                    | 41                    | 42                     | 43                     | 44                    | 45                   | 46                    | 47                   | 48                  | 49                   | 50                   | 51                    | 52                     | 53                    | 54                 | 55                   | 56                  | 57-71<br>lanthanoids   | 72                         | 73                    | 74                      | 75                   | 76                   | 77                      | 78                        | 79                       | 80                       | 81                    | 82                     | 83                     | 84                       | 85                      | 86                    |
| Rb<br>rubidium<br>85 | Sr<br>strontium<br>88 | Y<br>yttrium<br>89  | Zr<br>zirconium<br>90 | Nb<br>niobium<br>91   | Mo<br>molybdenum<br>92 | Tc<br>technetium<br>93 | Ru<br>ruthenium<br>94 | Rh<br>rhodium<br>95  | Pd<br>palladium<br>96 | Ag<br>silver<br>97   | Cd<br>cadmium<br>98 | In<br>indium<br>99   | Sn<br>tin<br>100     | Sb<br>antimony<br>101 | Te<br>tellurium<br>102 | I<br>iodine<br>103    | Xe<br>xenon<br>104 | Cs<br>caesium<br>133 | Ba<br>barium<br>137 | La<br>lanthanum<br>139 | Hf<br>hafnium<br>178       | Ta<br>tantalum<br>181 | W<br>tungsten<br>184    | Re<br>rhenium<br>186 | Os<br>osmium<br>190  | Ir<br>iridium<br>192    | Pt<br>platinum<br>195     | Au<br>gold<br>197        | Hg<br>mercury<br>201     | Tl<br>thallium<br>204 | Pb<br>lead<br>207      | Bi<br>bismuth<br>209   | Po<br>polonium<br>210    | At<br>astatine<br>210   | Rn<br>radon<br>222    |
| 87                   | 88                    | 89-103<br>actinoids | 104                   | 105                   | 106                    | 107                    | 108                   | 109                  | 110                   | 111                  | 112                 | 113                  | 114                  | 115                   | 116                    | 117                   | 118                | Fr<br>francium<br>87 | Ra<br>radium<br>88  | Ac<br>actinium<br>89   | Rf<br>rutherfordium<br>104 | Db<br>dubnium<br>105  | Sg<br>seaborgium<br>106 | Bh<br>bohrium<br>107 | Hs<br>hassium<br>108 | Mt<br>meitnerium<br>109 | Ds<br>darmstadtium<br>110 | Rg<br>roentgenium<br>111 | Cn<br>copernicium<br>112 | Nh<br>nihonium<br>113 | Fl<br>flerovium<br>114 | Mc<br>moscovium<br>115 | Lv<br>livermorium<br>116 | Ts<br>tennessine<br>117 | Og<br>oganeson<br>118 |

1  
H  
hydrogen  
1

**Key**  
atomic number  
atomic symbol  
name  
relative atomic mass

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

The volume of one mole of any gas is 24 dm<sup>3</sup> at room temperature and pressure (r.t.p.).