Cambridge Assessment International Education

# Cambridge IGCSE™ (9–1)

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*4585498912*

**CHEMISTRY** **0971/42**

Paper 4 Theory (Extended) **October/November 2021**

**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** This question is about states of matter.

**(a)** Complete the table, using ticks (✓) and crosses (✗), to describe the properties of gases, liquids and solids.

| state of matter | particles are touching | particles have random movement | particles are regularly arranged |
|---|---|---|---|
| gas | | | |
| liquid | | | |
| solid | | | |

[3]

**(b)** Substances can change state.

**(i)** Boiling and evaporation are two ways in which a liquid changes into a gas.

Describe **two** differences between boiling and evaporation.

1 .....

2 .....

[2]

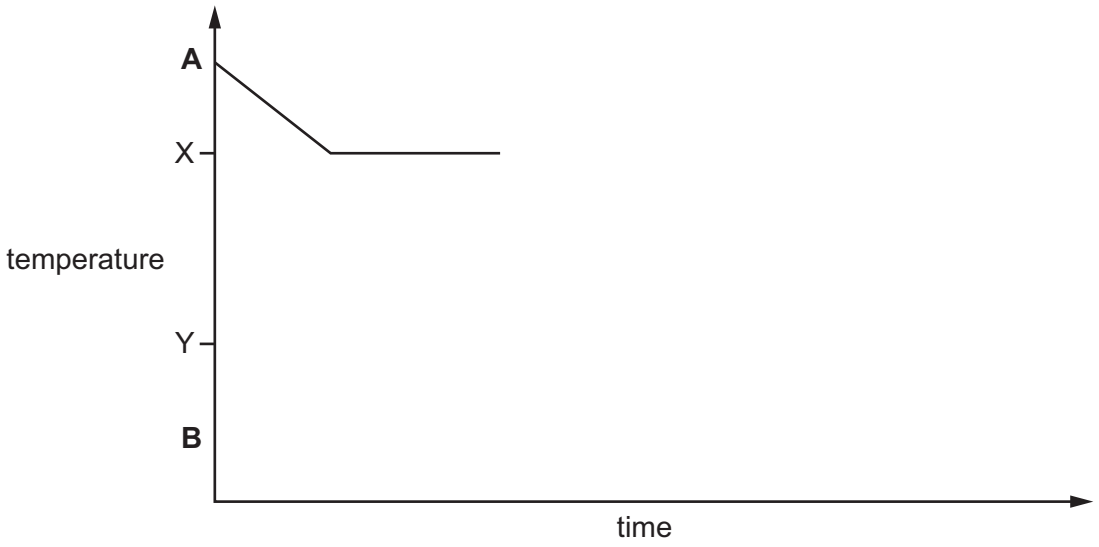
**(ii)** Name the change of state when:

- a gas becomes a liquid .....
- a solid becomes a gas. .....

[2]

**(c)** A substance boils at temperature X and melts at temperature Y.

Complete the graph to show the change in temperature over time as the substance cools from temperature **A** to temperature **B**.




[2]

**(d)** A solution is a mixture of a solute and a solvent.

**(i)** Name the process when a solid substance mixes with a solvent to form a solution.

..... [1]

**(ii)** Name the type of reaction when two solutions react to form an insoluble substance.

..... [1]

[Total: 11]



**[Turn over**

**2** Acids are important laboratory chemicals.

**(a)** Some acids completely dissociate in water to form ions.

**(i)** State the term applied to acids that completely dissociate in water.

..... [1]

**(ii)** Complete the equation to show the complete dissociation of sulfuric acid in water.

$H_2SO_4 \rightarrow$ ..... [2]

**(iii)** State the colour of methyl orange in sulfuric acid.

..... [1]

**(b)** The equation for the reaction between powdered zinc carbonate and dilute nitric acid is shown.

$ZnCO_3$..... + $2HNO_3$..... $\rightarrow$ $Zn(NO_3)_2$..... + $H_2O$..... + $CO_2$.....

**(i)** Complete the equation by adding state symbols. [2]

**(ii)** A student found that 2.5 g of zinc carbonate required 20 $cm^3$ of dilute nitric acid to react completely.

Calculate the concentration of dilute nitric acid using the following steps:

- calculate the mass of 1 mole of $ZnCO_3$

..... g

- calculate the number of moles of $ZnCO_3$ reacting

..... moles

- determine the number of moles of $HNO_3$ reacting

..... moles

- calculate the concentration of $HNO_3$.

..... $mol/dm^3$
[4]

[Total: 10]

**3** Atoms contain protons, neutrons and electrons.

**(a)** Complete the table to show the relative mass and the relative charge of a proton, a neutron and an electron.

| | relative mass | relative charge |
|---|---|---|
| proton | | |
| neutron | | |
| electron | $\frac{1}{1840}$ | |

[3]

**(b)** The table shows the number of protons, neutrons and electrons in some atoms and ions.

Complete the table.

| atom or ion | number of protons | number of neutrons | number of electrons |
|---|---|---|---|
| $^{32}_{16}S$ | | | |
| $^{39}_{19}K^{+}$ | | | |
| | 35 | 44 | 36 |

[5]

[Total: 8]

**4** Chlorine reacts with carbon monoxide to produce phosgene gas, $COCl_2(g)$. A catalyst is used.

$$Cl_2(g) + CO(g) \rightleftharpoons COCl_2(g)$$

The reaction is exothermic.

**(a)** Explain why the reaction is exothermic in terms of the energy changes of bond breaking and bond making.

.....

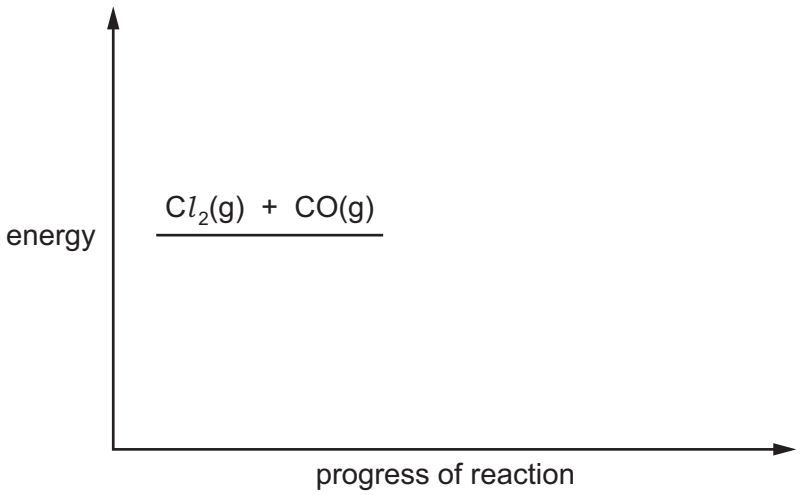
.....

..... [3]

**(b) (i)** Complete the energy level diagram for this reaction.

On your diagram show:

- the product of the reaction
- an arrow representing the energy change, labelled $\Delta H$
- an arrow representing the activation energy, labelled A.




[3]

**(ii)** State why a catalyst is used.

..... [1]

**(c)** Describe and explain the effect, if any, on the position of equilibrium when:

**(i)** the pressure is increased

.....

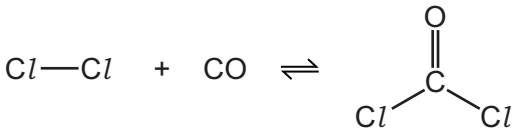
..... [2]

**(ii)** the temperature is increased.

.....

..... [2]

**(d)** The reaction between chlorine and carbon monoxide can be represented as shown.




When one mole of chlorine reacts with one mole of carbon monoxide, 230 kJ of energy is released.

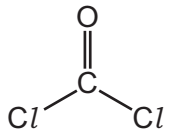
Some bond energies are shown in the table.

| bond | bond energy in kJ / mol |
|---|---|
| C*l*–C*l* | 240 |
| C=O | 745 |
| C–C*l* | 400 |

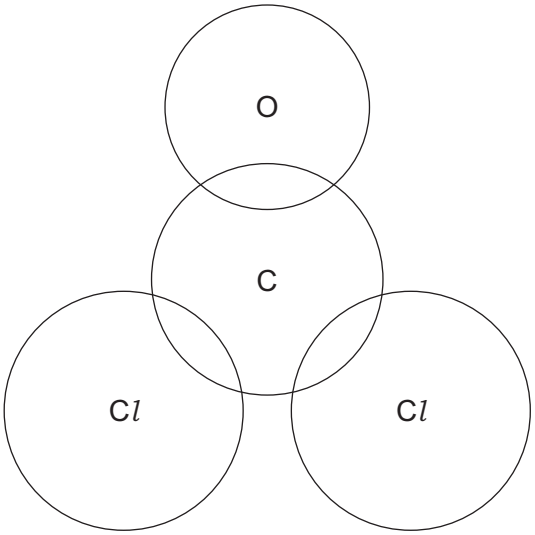
Use the information to calculate the energy of the bond between the C and the O in carbon monoxide, CO.

bond energy in carbon monoxide, CO = ..... kJ / mol [3]

**(e)** Complete the dot-and-cross diagram to show the electron arrangement in a molecule of $COCl_2$.




Show outer electrons only.




[3]

[Total: 17]

**5** Iron is a transition element. Potassium is a Group I element.

**(a)** Iron and potassium have the same type of bonding.

Name and describe the type of bonding in these two elements.

name .....

description .....

.....

.....

.....
[4]

**(b)** Transition elements and Group I elements have some similar physical properties.

They can both:

- be hammered into a shape
- conduct electricity
- be stretched into wires.

**(i)** Name the term used to describe the ability of elements to be hammered into a shape.

..... [1]

**(ii)** Describe what happens to the particles in iron when it is hammered into a shape.

.....

..... [1]

**(iii)** Suggest why copper, rather than other transition elements, is used for wires which conduct electricity.

..... [1]

**(c)** Transition elements are harder and stronger than Group I elements.

Describe how **two** other **physical** properties of transition elements are different from those of Group I elements.

1 .....

2 .....
[2]



**[Turn over**

**(d)** Chemical properties of some Group I elements are shown in the table.

| element | reaction with cold water | reaction with oxygen | flame test colour |
|---|---|---|---|
| lithium | ● steadily effervesces<br>● forms a colourless solution | very slowly forms an oxide layer | red |
| sodium | ● strongly effervesces<br>● forms a colourless solution | slowly forms an oxide layer | |
| potassium | ● very strongly effervesces<br>● forms a colourless solution | quickly forms an oxide layer | |
| rubidium | | | ruby red |

**(i)** Add to the table:

- the flame test colours for sodium and potassium
- the predicted reactions of rubidium with water and with oxygen.

[4]

**(ii)** Name the gas produced when Group I elements react with water.

..... [1]

**(iii)** Name the solution formed when potassium reacts with water.

..... [1]

**(iv)** Predict the pH of the colourless solution formed when potassium reacts with water.

..... [1]

**(v)** Write the chemical equation for the reaction of sodium with oxygen.

..... [2]

**(e)** Iron is a typical transition element. It is the catalyst used in the Haber process.

**(i)** Write the equation for the reaction that occurs in the Haber process.

..... [2]

**(ii)** State the temperature and pressure used in the Haber process. Include units.

temperature .....

pressure .....

[2]

[Total: 22]

**6** Ethanol, $C_2H_5OH$, belongs to the homologous series called alcohols.

**(a)** Write the general formula of alcohols.

..... [1]

**(b)** Explain why ethanol **cannot** be described as a hydrocarbon.

..... [1]

**(c)** Ethanol can be manufactured from different substances by reaction with steam or by fermentation.

**(i)** Give the formula of the substance which reacts with steam to form ethanol.

..... [1]

**(ii)** Name a substance which will undergo fermentation to form ethanol.

..... [1]

**(d)** Ethanol is a fuel.

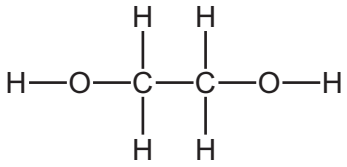
Write the chemical equation for the complete combustion of ethanol.

..... [2]



**[Turn over**

**(e)** Ethane-1,2-diol has two alcohol functional groups.



One molecule of ethane-1,2-diol will react with two molecules of ethanoic acid to form molecule **X**.

**X** has two ester functional groups and a molecular formula of $C_6H_{10}O_4$.

**(i)** State the empirical formula of **X**.

..... [1]

**(ii)** Draw the structure of **X**.

Show all of the atoms and all of the bonds.

[2]

**(iii)** Name the **other** substance formed in this reaction.

..... [1]

**(f)** Each alcohol functional group in ethane-1,2-diol reacts with acidified potassium manganate(VII) to form a different organic compound, **Y**.

**(i)** Name the functional groups formed in **Y**.

..... [1]

**(ii)** Draw the structure of **Y**.

Show all of the atoms and all of the bonds.

[1]

[Total: 12]

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## 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.).