Cambridge Assessment International Education

# Cambridge IGCSE™

CANDIDATE NAME



CENTRE NUMBER

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**CHEMISTRY**



**0620/42**

Paper 4 Theory (Extended)



**February/March 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.



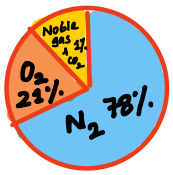
**INFORMATION**

- 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 **12** pages.




[Turn over




1 Using numbers only, state the:

(a) percentage of oxygen in clean, dry air ..... 21% ..... [1]

(b) typical operating temperature, **in °C**, used in the Haber process ..... 450°C ..... [1]

Exothermic reaction $N_2(g) + 3H_2(g) = 2NH_3(g)$ P = 200 atm Catalyst : Iron T = 450°C

Manufacture of Ammonia

(c) number of atoms in a diatomic molecule ..... 2 ..... [1]

2 atoms in one molecule

(d) maximum number of electrons in the second electron shell of an atom ..... 8 ..... [1]

first shell = $2e^-$ Second shell = $8e^-$

(e) number of hydrogen atoms in an alkane with 7 carbon atoms ..... 16 ..... [1]

(f) number of particles in **one** mole, in standard form. ..... $6.02 \times 10^{23}$ ..... [1]

General formula of Alkane : $C_nH_{2n+2}$ ($n$ = no. of carbons) $C_7H_{16}$

Avogadro Constant

[Total: 6]

2 This question is about ionic compounds.

(a) State what is meant by the term ionic bond.

Ionic bond is defined as strong electrostatic attraction between oppositely charged ions. (formed between a metal & non metal) [2]

(b) Potassium sulfide, $K_2S$, is an ionic compound.

Complete the dot-and-cross diagram in Fig. 2.1 of the ions in potassium sulfide.

Show the charges on the ions.

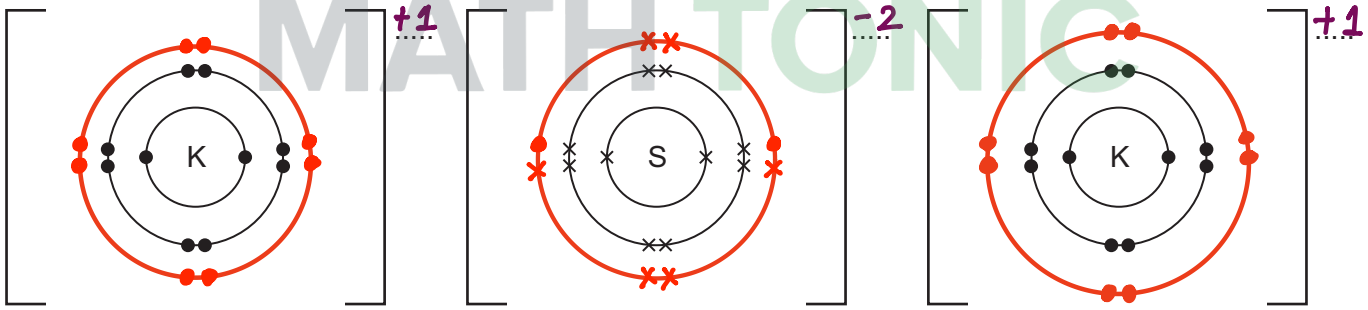



Fig. 2.1 [3]

19 → Proton number

K (Pottasium)

39

No. of Protons = No. of electrons

19 electrons

Electronic configuration

2 8 8 (1)

Pottasium is going to donate one electron giving a charge of +1

16 → Proton number

S (Sulphur)

32

16 electrons

Electronic configuration

2 8 (6) ← $2e^-$

Sulphur will recieve another two electron in order to become complete oct.

2 8 8

**(c)** Ionic compounds form giant ionic lattices.

**(i)** Fig. 2.2 shows part of the giant ionic lattice structure of sodium chloride.

Complete the diagram in Fig. 2.2 to show the ions present. Use '+' for sodium ions and '–' for chloride ions. One chloride ion has been completed for you.

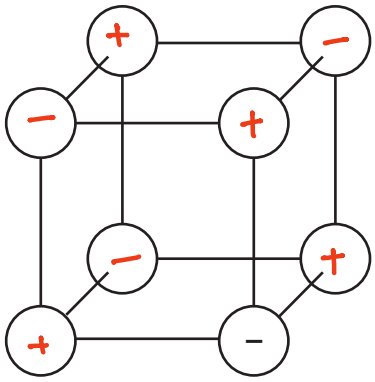


Fig. 2.2

[Negative will be attracted to positive
Draw opposite charges connected to each other.]

Cation: Any atom donate $e^-$ → forms a positive ion

Anions: Any atom recieves $e^-$ → forms negative ion

[2]

**(ii)** State the name given to any positive ion.

Cations [1]

**(d)** Ionic compounds can be decomposed by the passage of an electric current using inert electrodes.

Electrolysis is a process in which a molten ionic Compound is broken down by an electric current.

**(i)** State the name of this process.

Electrolysis [1]

**(ii)** Write the ionic half-equation for the reaction which takes place at the anode when **molten** potassium bromide, KBr, is decomposed by the passage of an electric current.

$2Br^- \rightarrow Br_2 + 2e^-$ [2]

**(iii)** Name the products and state the observations at the negative and positive electrodes when **dilute aqueous** potassium bromide, KBr, is decomposed by the passage of an electric current.

product at the negative electrode

Hydrogen gas

observations at the negative electrode

Colorless bubbles

products at the positive electrode

water and oxygen gas

observations at the positive electrode

Colorless bubbles

[5]

[Total: 16]

3 The halogens are a group of elements in the Periodic Table.

Chlorine is a member of this group.

**(a)** State the group number of the halogens.

Group VII Group 7 [1]

**(b)** State how many halogens there are in this group.

Six [1]

**(c)** Suggest the identity of the halogen which:

**(i)** has the highest density

As the element goes down the group it gets heavier (density increases)

Ts - Tennessine → bottom of the group [1]

**(ii)** is the most reactive.

As the element moves up the group it is more reactive.

Flourine → top of the group [1]

**(d)** State the name of the negative ions (anions) formed by halogens.

Halides [1]

**(e)** State how many occupied electron shells there are in a bromine atom.

Four (Bromine atom is placed in period 4, which means it has four shells that occupy electrons) [1]

**(f)** Name the noble gas which has the same electronic configuration as a $Br^-$ ion.

Krypton (Kr) [1]

**(g)** Aqueous chlorine, $Cl_2$, reacts with aqueous potassium iodide, KI.
One of the products formed is iodine, $I_2$.

**(i)** Complete and balance the ionic equation for the reaction between $Cl_2$ and $I^-$ ions.
State symbols are **not** required.

$$Cl_2 + 2\,I^- \rightarrow 2\,Cl^- + I_2$$

[2]

**(ii)** Explain why this reaction is defined as a redox reaction.

Give your answer in terms of electron transfer.

Oxidation and reduction takes place at the same time.

Chlorine gains electron and is reduced and Iodide Ions lose electrons and are oxidised. [2]

**(h)** Give the colour and state of iodine at room temperature and pressure.

colour Grey-Black

state Solid [2]

| Group 7 elements | Physical State (Room Temp.) | Colour (Room Temp) |
|---|---|---|
| Flourine | Gas | Yellow |
| Chlorine | Gas | Green |
| Bromine | Liquid | Red-brown |
| Iodine | Solid | Grey-Black |

(forms purple vapour when heated)

[Total: 13]

4 Carbonyl chloride, $COCl_2$, is manufactured by reacting carbon monoxide with chlorine.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -105 \text{ kJ/mol}$$

Reversible. Negative symbol indicates that (Exothermic reaction)

forward reaction is a exothermic reaction.

The process takes place in a closed system, and an equilibrium is reached.
The conditions for this process are 200 °C and 200 kPa.

**(a)** Explain what is meant by the term closed system.

A system in which no reactants or product can enter or leave. [1]

**(b)** State what the symbol $\Delta H$ represents.

Enthalpy change (Enthalpy change is the heat that passes into or out of the system during a reaction) [1]

**(c)** State how the value of $\Delta H$ shows that the forward reaction is exothermic.

$\Delta H$ value is negative. [1]

**(d)** Deduce the value of $\Delta H$ for the reverse reaction. Include a sign in your answer.

+105 kJ/mol [1]

If forward reaction is exothermic then opposite reaction is endothermic.

**(e)** Complete Table 4.1 to show the effect, if any, on the concentration of $COCl_2(g)$ at equilibrium when the following changes to the conditions are applied.

Use only the words **increases**, **decreases** or **no change**.

Product of reaction

**Table 4.1**

| change to conditions | effect on the concentration of $COCl_2(g)$ at equilibrium | Position of Equillibrium |
|---|---|---|
| the temperature is increased | decreases | Shifts left |
| some CO is added | Increases | Shifts right |
| the pressure is increased | Increases | Shifts right |
| a catalyst is added | No change | No Effect |

When catalyst is added, only Rate of reaction (speed) increases.

[4]

for this case Endothermic reaction is backward reaction

# NOTES :

Increasing temperature favours the endothermic reaction.

So position of equillibrium shifts in favour of endothermic reaction.

Increasing Concentration of reactants favours the formation of more products

- Position of equillibrium shifts to right to reduce the Concentration of reactants.

Increasing pressure favours the side with fewer moles of gas.

- Position of equillibrium shifts to side with fewer moles of gas.

**(f)** The equation for the reaction can be represented as shown in Fig. 4.1.

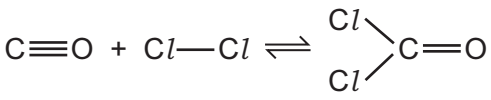



**Fig. 4.1**

Table 4.2 shows some bond energies.

**Table 4.2**

| bond | C≡O | Cl–Cl | C–Cl |
|---|---|---|---|
| bond energy in kJ/mol | 1075 | 240 | 340 |

Use the bond energies in Table 4.2 and the value of $\Delta H$ for the reaction to calculate the bond energy, in kJ/mol, of the C=O bond.

Use the following steps.

- Calculate the energy needed to break the bonds in the reactants.

1075 + 240 = 1315

1315 ..... kJ

- Calculate the energy released when the bonds in carbonyl chloride form.

1315 – (–105)

1420 ..... kJ

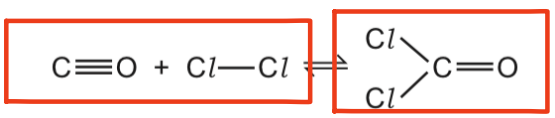
- Calculate the bond energy of the C=O bond.

2 (C–Cl) + 1 (C=O) = 1420

(2 × 340) + 1 (C=O) = 1420

Energy (C=O) = 1420 – 680 = 740 ..... kJ/mol

[3]




Bond Broken – Bond formed = ΔH

Bond formed = Bond Broken – ΔH

= 1315 – (–105) = 1420 kJ

**(g)** Complete the dot-and-cross diagram in Fig. 4.2 of a molecule of carbonyl chloride.

Show outer shell electrons only.

Electronic Configuration

Cl : 2 8 7 ← need 1e⁻ to be stable

C : 2 4 ← need 4e⁻

O : 2 6 ← need 2e⁻

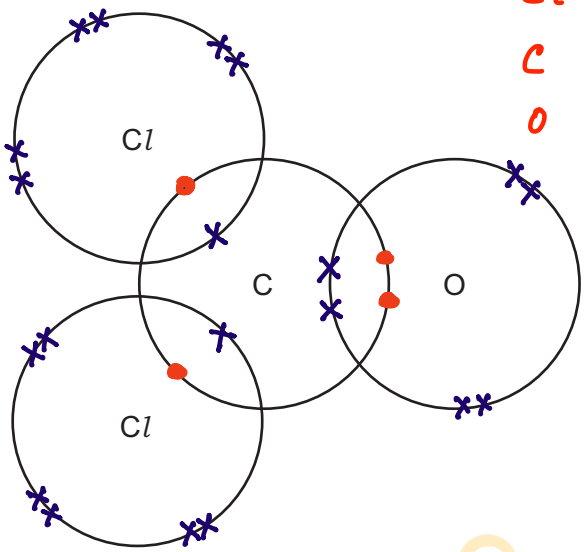



**Fig. 4.2**

[3]

[Total: 14]

5 Manganese is the element with atomic number 25 in the Periodic Table.
Calcium is the element with atomic number 20 in the Periodic Table.

**(a)** Complete Table 5.1 to show the number of protons, neutrons and electrons in the $^{55}Mn$ atom and the $^{42}Ca^{2+}$ ion.

Atomic Number = Proton No.

55 Mn

Nucleon = P+N

**Table 5.1**

| | $^{55}Mn$ | $^{42}Ca^{2+}$ (Donated) |
|---|---|---|
| protons | 25 | 20 |
| neutrons | 55 − 25 = 30 | 42 − 20 = 22 |
| electrons | 25 | 18 |

[3]

**(b)** Manganese forms several oxides. The formulae of some of these oxides are shown.

↳ is in transition element

Transition Element Properties
# Different Oxidation Number
# Acts as a Catalyst
# High Melting Point and high densities
# can form coloured oxides.

$MnO$
$Mn_2O_3$
$Mn_3O_4$
$MnO_2$
$Mn_2O_7$

**(i)** Suggest why manganese is expected to form coloured oxides.

Because manganese is a transition element [1]

**(ii)** State which other property of manganese is shown by the formation of several oxides.

Different Oxidation Number [1]

**(iii)** State the formula of manganese(II) oxide.

Oxidation No. of Mn is 2+

Mn(2+) O(2−)

$Mn_2O_2$

MnO (After simplifying) [1]

**(c)** $Mn_3O_4$ is found in an ore of manganese. Manganese metal can be extracted from $Mn_3O_4$ using aluminium as the reducing agent.

**(i)** Define the term reducing agent.

Reducing agent is a Substance that causes another Substance to be reduced. A reducing agent is itself oxidised (it loses electrons) [2]

**(ii)** Complete the symbol equation by inserting the formula of the missing product and balancing the equation.

$3\ Mn_3O_4 + 8\ Al \rightarrow 4\ Al_2O_3 + 9\ Mn$

Al(3+) O(−2)

$Al_2O_3$

[2]

**(d)** $MnO_2$ reacts with dilute hydrochloric acid as shown in the equation.

$$MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$$

**(i)** Calculate the volume of chlorine gas formed, in $cm^3$, at r.t.p. when excess $MnO_2$ reacts with 50.0 $cm^3$ of 0.200 mol / $dm^3$ $HCl$.

50 $cm^3$ → $50 \times \frac{1}{1000}$ $dm^3$

Use the following steps.

- Calculate the number of moles of $HCl$ used.

Concentration = $\frac{mol}{volume}$ ⇒ mol = Concentration × volume

= 0.2 $\frac{mol}{dm^3}$ × 0.05

0.01 ..... mol

- Determine the number of moles of $Cl_2$ formed.

4 HCl ⟶ 1 $Cl_2$ (4 mol of HCl will produce 1 mol of $Cl_2$ from given reaction)

0.01 HCl ⟶ $\frac{0.01}{4}$ $Cl_2$

0.0025 ..... mol

- Calculate the volume of $Cl_2$ formed.

Volume = mol × 24 $dm^3$

= 0.0025 × 24 $dm^3$

= 0.6 $dm^3$

= 0.6 × 1000 $cm^3$

60 ..... $cm^3$

[3]

**(ii)** Describe a test for chlorine gas.

test ..... Damp blue litmus paper .....

observations ..... Bleached .....

[1]

**(iii)** Explain, in terms of collision theory, why decreasing the temperature decreases the rate of this reaction.

Decreasing the temperature

# Reduces the Kinetic Energy of the particles.

# Particles move more slowly and collides less frequently

# Fewer particles have the activation Energy

# Therefore, fewer Successful Collision.

..... [3]

[Total: 17]

6 The structural formulae of two compounds, **A** and **B**, are shown.

$C_nH_{2n}$ { $C_3H_6$, $C_4H_8$

| A | B |
|---|---|
| $CH_2=CHCH_3$ | $CH_3CH=CHCH_3$ |

**A** and **B** are members of the same homologous series.

**(a)** Give **two** reasons why the structural formulae of **A** and **B** show they are members of the same homologous series.

1 Same functional group

2 Same general formula

[2]

**(b)** Explain why **A** and **B** are both hydrocarbons.

Only Consists of Hydrogen and Carbon atoms [1]

**(c)** Write the symbol equation for the complete combustion of **A**.

$2C_3H_6 + 9O_2 \rightarrow 6CO_2 + 6H_2O$ [2]

**(d)** Deduce the empirical formula of **A**.

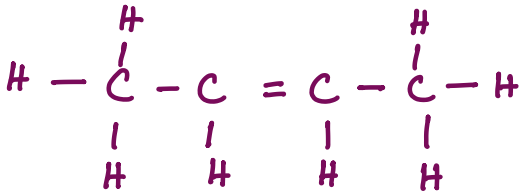
$CH_2$ [1]

**(e)** Name compound **B**.

Butene or But-2-ene [1]

**(f)** A structural isomer of **B** is a member of the same homologous series.

Draw the displayed formula of this structural isomer of **B**.



[1]

For incomplete Combustion:

$X + O_2 \rightarrow CO + H_2O$

↓ carbon monoxide

**(g)** Compound **B** reacts with aqueous bromine at room temperature to form product **C**. The equation is shown.

$$\underset{\textbf{B}}{CH_3CH{=}CHCH_3} + Br_2 \rightarrow \underset{\textbf{C}}{CH_3CHBrCHBrCH_3}$$

**(i)** State why this is an addition reaction.

Because There is only one product. [1]

**(ii)** Describe the colour change in aqueous bromine during this reaction.

from Orange to colorless [1]

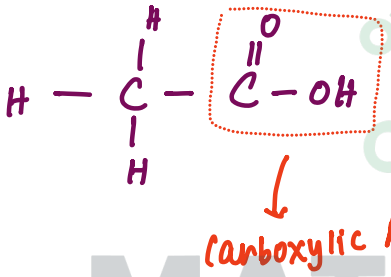
**(iii)** Name product **C**.

2,3 - dibromo butane [1]

**(h)** Under certain conditions, **one** mole of **B** reacts with oxygen to form **two** moles of carboxylic acid **D**.

Carboxylic acid **D** has **two** carbon atoms.

**(i)** Draw the displayed formula of carboxylic acid **D**.




[1]

**(ii)** Name carboxylic acid **D**.

Ethanoic Acid [1]

**(iii)** Complete the symbol equation for this reaction.

$CH_3CH{=}CHCH_3$ + 2 $O_2$ → 2 $CH_3COOH$

[1]

[Total: 14]

If Bromine was reacted with
$Br_2$ + Alkane .
↓ No reaction (because Alkane is saturated)
Orange to orange

# The Periodic Table of Elements

Alkaline metals

Halogens

Noble gases

| Group I | Group II | | | | | | Group III | Group IV | Group V | Group VI | Group VII | Group 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

(Group 3 to Group 12)
Transition elements

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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.).