Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER



**CHEMISTRY** **9701/24**

Paper 2 AS Level Structured Questions **October/November 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 60.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has **16** pages. Any blank pages are indicated.




[Turn over

**1** The Group 17 elements are oxidising agents.

**(a) (i)** Explain how the Group 17 elements act as oxidising agents.

.....

..... [1]

**(ii)** Write an equation to show the reaction in which $Cl_2$ oxidises aluminium metal.

..... [1]

**(iii)** A student heats equal amounts of $I_2(g)$ and $H_2(g)$ in a sealed flask. The student leaves the contents to cool.

State what you would observe during the reaction.

..... [1]

**(b)** $Cl_2$ and $Br_2$ can each react with $NH_3$ to give $N_2$ and a hydrogen halide, HX.

$$3X_2 + 2NH_3 \rightarrow N_2 + 6HX \qquad X = Cl \text{ or } Br$$

The relative bond strengths of X–X and H–X determine the difference in enthalpy change of the two reactions.

**(i)** Describe and explain the difference in the X–X bond strengths of $Cl_2$ and $Br_2$.

.....

.....

.....

..... [2]

**(ii)** Describe the relative thermal stabilities of HCl and HBr.

..... [1]

**(iii)** Define enthalpy change of formation, $\Delta H_f$.

.....

.....

..... [2]

**(iv)** Table 1.1 gives data relevant to the reaction of $Cl_2(g)$ with $NH_3(g)$.

**Table 1.1**

| compound | enthalpy change of formation, $\Delta H_f$ / kJ mol$^{-1}$ |
|---|---|
| $NH_3(g)$ | –46 |
| $HCl(g)$ | –92 |

Use the data in Table 1.1 to calculate the enthalpy change of the reaction of $Cl_2(g)$ with $NH_3(g)$.

enthalpy change of reaction = ..... kJ mol$^{-1}$ [2]

**(v)** $I_2$ reacts with $NH_3$ to form $NI_3$.

Predict the shape of a molecule of $NI_3$. Explain your answer.

shape .....

explanation .....

.....

[2]

**(c)** Table 1.2 shows some information about reactions of NaC$l$, NaBr and NaI.

**Table 1.2**

| | **NaC$l$** | **NaBr** | **NaI** |
|---|---|---|---|
| observation with $Ag^+(aq)$ | white precipitate | | |
| type of reaction with concentrated $H_2SO_4$ | acid–base | acid–base, then redox | acid–base, then redox |
| observations with concentrated $H_2SO_4$ | | | • black solid<br>• yellow solid<br>• effervescence |

**(i)** Complete Table 1.2. [4]

**(ii)** Suggest an identity for the species that produces each observation in the reaction of NaI with concentrated $H_2SO_4$.

black solid .....

yellow solid .....

effervescence .....

[2]

**(d)** Table 1.3 gives some information about $MgCl_2$ and $SiCl_4$.

**Table 1.3**

| | **$MgCl_2$** | **$SiCl_4$** |
|---|---|---|
| electrical conductivity when liquid | conducts | does **not** conduct |
| observation when added to water | dissolves | vigorous reaction |

**(i)** Explain the difference between the electrical conductivity of liquid $MgCl_2$ and of liquid $SiCl_4$. Refer to bonding and relevant particles in your answer.

.....

.....

.....

.....

..... [2]

**(ii)** Suggest the pH of the solutions that form when each chloride is added to water.

$MgCl_2$ ..... $SiCl_4$ .....

[2]

[Total: 22]

**BLANK PAGE**

**2** Aluminium oxide, $Al_2O_3$, and phosphorus(V) oxide, $P_4O_{10}$, are both used as reagents and catalysts.

**(a)** The melting point of $Al_2O_3$ is 2072 °C. The melting point of $P_4O_{10}$ is 340 °C.

Explain the difference in the melting points of these two compounds.

.....

.....

.....

..... [3]

**(b)** A 5.00 $dm^3$ sealed flask contains 0.400 mol of CO(g) and 0.800 mol of $H_2$(g) and an $Al_2O_3$ catalyst. The flask is heated to a temperature of 290 °C and allowed to reach equilibrium. Equation 1 shows the reaction.

equation 1 $\quad CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

The equilibrium constant, $K_c$, of equation 1 is given.

$$K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$$

**(i)** State the units of $K_c$.

..... [1]

**(ii)** The equilibrium mixture contains 0.280 mol of $CH_3OH$(g).

Calculate the value of $K_c$.

Give your answer to **three** significant figures.

value of $K_c$ = ..... [3]

**(iii)** State and explain the effect, if any, on the value of $K_c$ when the overall pressure in the sealed flask is increased.

.....

..... [1]

**(c)** $P_4O_{10}$ catalyses the reversible reaction of CO with $H_2$ to form $CH_3OH$.

equation 1 $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

$P_4O_{10}$ then acts as a dehydrating agent, causing $CH_3OH$ to form $CH_3OCH_3$.

**(i)** Explain how the presence of a catalyst affects a chemical reaction.

.....

.....

..... [1]

**(ii)** Construct an equation for the dehydration reaction of $CH_3OH$ to form $CH_3OCH_3$.

..... [1]

**(iii)** Write an equation to show the reaction of $P_4O_{10}$ with an excess of water.

..... [1]

[Total: 11]

**3** Propan-2-ol, $(CH_3)_2CHOH$, is sometimes added to fuel to help it burn.

Fig. 3.1 shows some reactions of propan-2-ol.

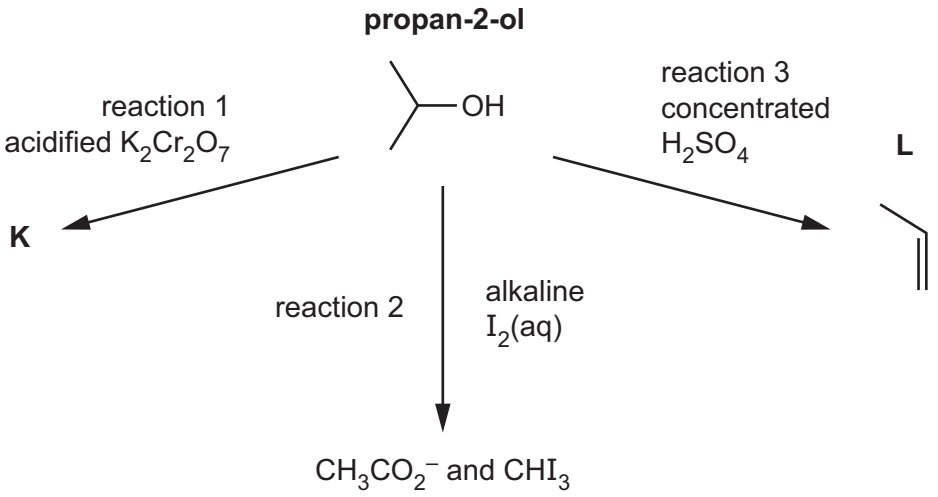


**Fig. 3.1**

**(a) (i)** Draw the structure of organic compound **K**.

[1]

**(ii)** State an observation you would make in reaction 2.

..... [1]

**(iii)** State the type of reaction that is shown in reaction 3.

..... [1]

**(iv)** Complete Fig. 3.2 to show the pi ($\pi$) bond in **L** that is formed from orbital overlap.

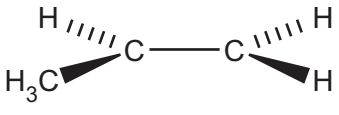


**Fig. 3.2**

[1]

**(b)** Propan-2-ol reacts with sodium to produce $(CH_3)_2CH–O^-$ anions.

These anions react with 2-bromopropane to form compound **N**, as shown in Fig. 3.3.

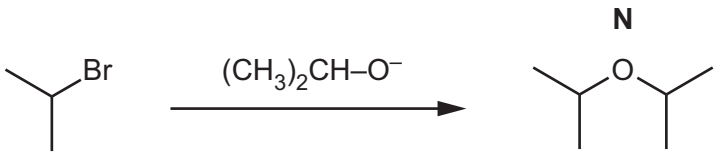


**Fig. 3.3**

**(i)** Write an equation for the reaction of propan-2-ol with sodium.

..... [1]

**(ii)** The reaction of 2-bromopropane with $(CH_3)_2CH–O^-$ anions follows an $S_N1$ mechanism.

Complete Fig. 3.4 to show this mechanism. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.


**Fig. 3.4**

[3]

**(iii)** Suggest how the rate of the $S_N1$ reaction would change, if at all, if 2-chloropropane were used instead of 2-bromopropane.

Explain your answer.

.....

.....

..... [2]

**(iv)** **N** is also added to petrol to make it burn more smoothly.

Construct an equation for the complete combustion of **N**, $C_6H_{14}O$.

$C_6H_{14}O$ ..... [1]

[Total: 11]

**4** Compounds **P** and **Q** are structural isomers.

**P** **Q**

**Fig. 4.1**

**(a) (i)** Define structural isomerism.

.....

..... [2]

**(ii)** **P** shows geometrical isomerism.

Draw the geometrical isomer of **P**. Explain why the two isomers are **not** identical.

geometrical isomer of **P**

explanation .....

.....

.....

[2]

**(iii)** Both **P** and **Q** react with aqueous bromine.

Name the mechanism of this reaction.

..... [1]

**(iv)** **Q** is oxidised by hot concentrated acidified $KMnO_4(aq)$, forming two different organic products.

Construct an equation for this reaction. Use [O] to represent an atom of oxygen from the oxidising agent.

$(CH_3)_2C{=}CHCH_3$ ..... [2]

**(v)** **Q** reacts with HBr(g) to produce two structural isomers, **R** and **S**, as shown in Fig. 4.2.

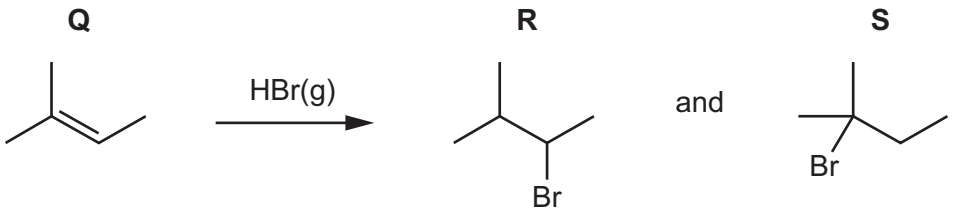


**Fig. 4.2**

State and explain why isomer **S** is the major product of the reaction.

.....

.....

..... [2]

**(vi)** The mass spectrum of **R** shows peaks at *m/e* = 150 and *m/e* = 152.

Suggest structures for the ions responsible for these peaks.

| peak at *m/e* = 150 | peak at *m/e* = 152 |
| --- | --- |
| | |

[2]

**(b)** Fig. 4.3 shows a synthesis starting from **T**, a different isomer of **R** and **S**.

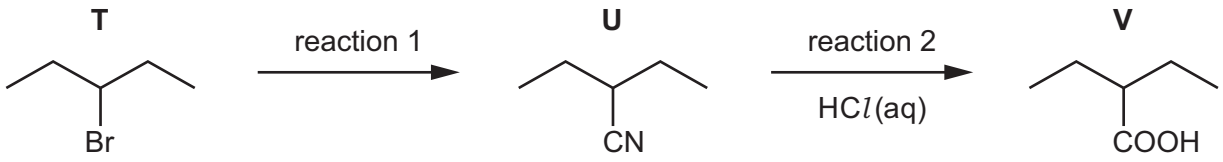


**Fig. 4.3**

**(i)** Identify the reagent and conditions for reaction 1.

..... [1]

**(ii)** Reaction 2 is a hydrolysis reaction.

Construct an equation for reaction 2.

$(C_2H_5)_2CHCN$ ..... [1]

**(iii)** **V** reacts with propan-2-ol in the presence of a catalytic amount of $H_2SO_4$ to form organic compound **W**.

Complete Table 4.1 to give details of this reaction.

**Table 4.1**

| | reaction of **V** with propan-2-ol |
|---|---|
| type of reaction | |
| functional group formed | |
| molecular formula of organic product **W** | |

[3]

[Total: 16]

**BLANK PAGE**



**BLANK PAGE**

## Important values, constants and standards

| | |
|---|---|
| molar gas constant | $R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$ |
| Faraday constant | $F = 9.65 \times 10^{4}\,\text{C mol}^{-1}$ |
| Avogadro constant | $L = 6.02 \times 10^{23}\,\text{mol}^{-1}$ |
| electronic charge | $e = -1.60 \times 10^{-19}\,\text{C}$ |
| molar volume of gas | $V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K)<br>$V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions |
| ionic product of water | $K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C)) |
| specific heat capacity of water | $c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$) |

## The Periodic Table of Elements

| Group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | | | 1 H hydrogen 1.0 | | | | | | | | | | 2 He helium 4.0 |
| 3 Li lithium 6.9 | 4 Be beryllium 9.0 | | | | | | | | | | | 5 B boron 10.8 | 6 C carbon 12.0 | 7 N nitrogen 14.0 | 8 O oxygen 16.0 | 9 F fluorine 19.0 | 10 Ne neon 20.2 |
| 11 Na sodium 23.0 | 12 Mg magnesium 24.3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 Al aluminium 27.0 | 14 Si silicon 28.1 | 15 P phosphorus 31.0 | 16 S sulfur 32.1 | 17 Cl chlorine 35.5 | 18 Ar argon 39.9 |
| 19 K potassium 39.1 | 20 Ca calcium 40.1 | 21 Sc scandium 45.0 | 22 Ti titanium 47.9 | 23 V vanadium 50.9 | 24 Cr chromium 52.0 | 25 Mn manganese 54.9 | 26 Fe iron 55.8 | 27 Co cobalt 58.9 | 28 Ni nickel 58.7 | 29 Cu copper 63.5 | 30 Zn zinc 65.4 | 31 Ga gallium 69.7 | 32 Ge germanium 72.6 | 33 As arsenic 74.9 | 34 Se selenium 79.0 | 35 Br bromine 79.9 | 36 Kr krypton 83.8 |
| 37 Rb rubidium 85.5 | 38 Sr strontium 87.6 | 39 Y yttrium 88.9 | 40 Zr zirconium 91.2 | 41 Nb niobium 92.9 | 42 Mo molybdenum 95.9 | 43 Tc technetium – | 44 Ru ruthenium 101.1 | 45 Rh rhodium 102.9 | 46 Pd palladium 106.4 | 47 Ag silver 107.9 | 48 Cd cadmium 112.4 | 49 In indium 114.8 | 50 Sn tin 118.7 | 51 Sb antimony 121.8 | 52 Te tellurium 127.6 | 53 I iodine 126.9 | 54 Xe xenon 131.3 |
| 55 Cs caesium 132.9 | 56 Ba barium 137.3 | 57–71 lanthanoids | 72 Hf hafnium 178.5 | 73 Ta tantalum 180.9 | 74 W tungsten 183.8 | 75 Re rhenium 186.2 | 76 Os osmium 190.2 | 77 Ir iridium 192.2 | 78 Pt platinum 195.1 | 79 Au gold 197.0 | 80 Hg mercury 200.6 | 81 Tl thallium 204.4 | 82 Pb lead 207.2 | 83 Bi bismuth 209.0 | 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 138.9 | 58 Ce cerium 140.1 | 59 Pr praseodymium 140.9 | 60 Nd neodymium 144.2 | 61 Pm promethium – | 62 Sm samarium 150.4 | 63 Eu europium 152.0 | 64 Gd gadolinium 157.3 | 65 Tb terbium 158.9 | 66 Dy dysprosium 162.5 | 67 Ho holmium 164.9 | 68 Er erbium 167.3 | 69 Tm thulium 168.9 | 70 Yb ytterbium 173.1 | 71 Lu lutetium 175.0 |
| actinoids | 89 Ac actinium – | 90 Th thorium 232.0 | 91 Pa protactinium 231.0 | 92 U uranium 238.0 | 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 – |