



# Cambridge International AS & A Level

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## 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.

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,  $HX$ .



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  $\text{Cl}_2(\text{g})$  with  $\text{NH}_3(\text{g})$ .

**Table 1.1**

| compound                | enthalpy change of formation, $\Delta H_f / \text{kJ mol}^{-1}$ |
|-------------------------|-----------------------------------------------------------------|
| $\text{NH}_3(\text{g})$ | −46                                                             |
| $\text{HCl}(\text{g})$  | −92                                                             |

Use the data in Table 1.1 to calculate the enthalpy change of the reaction of  $\text{Cl}_2(\text{g})$  with  $\text{NH}_3(\text{g})$ .

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

(v)  $\text{I}_2$  reacts with  $\text{NH}_3$  to form  $\text{NI}_3$ .

Predict the shape of a molecule of  $\text{NI}_3$ . Explain your answer.

shape .....

explanation .....

..... [2]



(c) Table 1.2 shows some information about reactions of NaCl, NaBr and NaI.

Table 1.2

|                                                            | NaCl              | NaBr                  | NaI                                                                                                        |
|------------------------------------------------------------|-------------------|-----------------------|------------------------------------------------------------------------------------------------------------|
| observation with $\text{Ag}^+(\text{aq})$                  | white precipitate |                       |                                                                                                            |
| type of reaction with concentrated $\text{H}_2\text{SO}_4$ | acid–base         | acid–base, then redox | acid–base, then redox                                                                                      |
| observations with concentrated $\text{H}_2\text{SO}_4$     |                   |                       | <ul style="list-style-type: none"> <li>black solid</li> <li>yellow solid</li> <li>effervescence</li> </ul> |

(i) Complete Table 1.2. [4]

(ii) Suggest an identity for the species that produces each observation in the reaction of NaI with concentrated  $\text{H}_2\text{SO}_4$ .

black solid .....

yellow solid .....

effervescence .....

[2]

(d) Table 1.3 gives some information about  $\text{MgCl}_2$  and  $\text{SiCl}_4$ .

Table 1.3

|                                     | $\text{MgCl}_2$ | $\text{SiCl}_4$         |
|-------------------------------------|-----------------|-------------------------|
| electrical conductivity when liquid | conducts        | does <b>not</b> conduct |
| observation when added to water     | dissolves       | vigorous reaction       |

(i) Explain the difference between the electrical conductivity of liquid  $\text{MgCl}_2$  and of liquid  $\text{SiCl}_4$ . 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.

$\text{MgCl}_2$  .....  $\text{SiCl}_4$  ..... [2]

[Total: 22]





- 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  $2072^\circ C$ . The melting point of  $P_4O_{10}$  is  $340^\circ C$ .

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

.....

.....

.....

..... [3]

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



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  $0.280\text{ mol}$  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  $CH_3OH$ .



$P_4O_{10}$  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,  $(\text{CH}_3)_2\text{CHOH}$ , is sometimes added to fuel to help it burn.

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

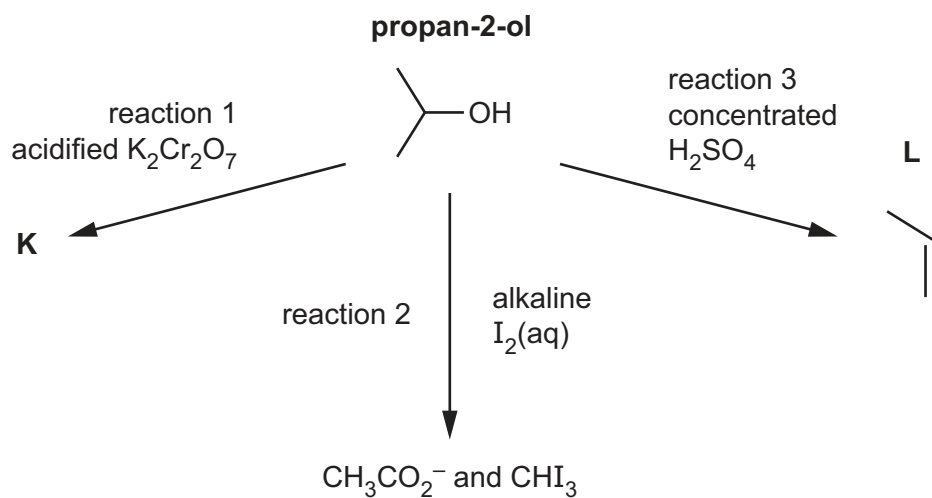


Fig. 3.1

- (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.

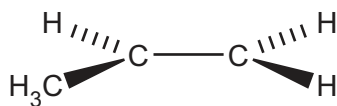


Fig. 3.2

[1]



- (b) Propan-2-ol reacts with sodium to produce  $(\text{CH}_3)_2\text{CH}-\text{O}^-$  anions.

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

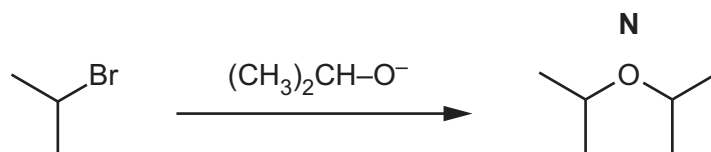


Fig. 3.3

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

..... [1]

- (ii) The reaction of 2-bromopropane with  $(\text{CH}_3)_2\text{CH}-\text{O}^-$  anions follows an  $\text{S}_{\text{N}}1$  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  $\text{S}_{\text{N}}1$  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**,  $\text{C}_6\text{H}_{14}\text{O}$ .

$\text{C}_6\text{H}_{14}\text{O}$  ..... [1]

[Total: 11]



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



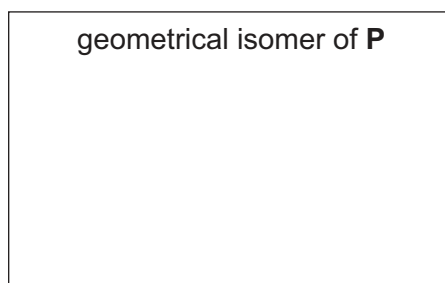
Fig. 4.1

(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.



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  $\text{KMnO}_4(\text{aq})$ , forming two different organic products.

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

$(\text{CH}_3)_2\text{C}=\text{CHCH}_3$  ..... [2]



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

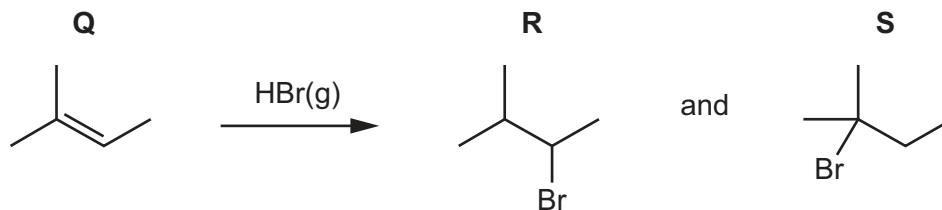


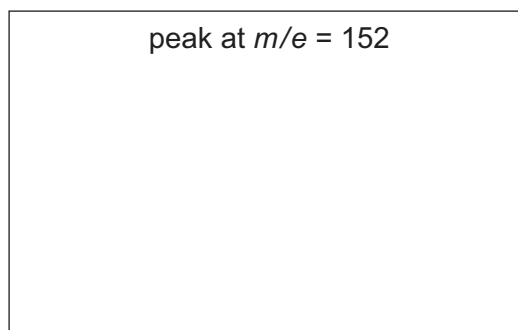
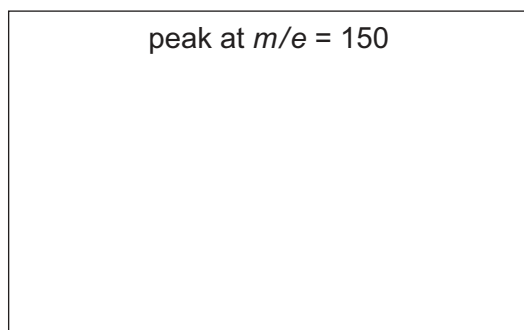
Fig. 4.2

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.



[2]



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

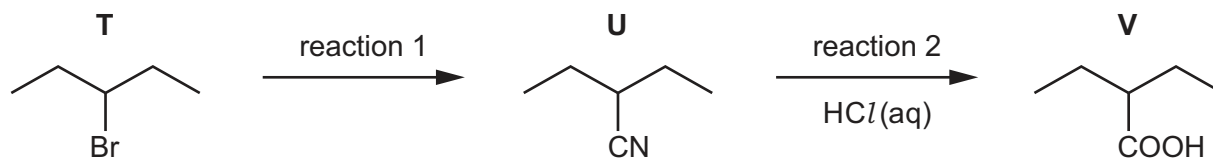


**Fig. 4.3**

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

..... [1]

(ii) Reaction 2 is a hydrolysis reaction.

Construct an equation for reaction 2.

$(\text{C}_2\text{H}_5)_2\text{CHCN}$  ..... [1]

(iii) **V** reacts with propan-2-ol in the presence of a catalytic amount of  $\text{H}_2\text{SO}_4$  to form organic compound **W**.

Complete Table 4.1 to give details of this reaction.

**Table 4.1**

|                                               | reaction of <b>V</b> with propan-2-ol |
|-----------------------------------------------|---------------------------------------|
| type of reaction                              |                                       |
| functional group formed                       |                                       |
| molecular formula of organic product <b>W</b> |                                       |

[3]

[Total: 16]







## 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 J g <sup>-1</sup> K <sup>-1</sup> )                                                    |



The Periodic Table of Elements

| Group                  |                         |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        |                         |                         |                         |                          |                        |                       |  |  |
|------------------------|-------------------------|----------------------------------------------------------------|-------------------------|-----------------------|--------------------------|-------------------------|--------------------------|------------------------|--------------------------|-----------------------|------------------------|-------------------------|-------------------------|-------------------------|--------------------------|------------------------|-----------------------|--|--|
| 1                      | 2                       | Key                                                            |                         |                       |                          |                         |                          |                        |                          |                       |                        | 13                      | 14                      | 15                      | 16                       | 17                     | 18                    |  |  |
|                        |                         | <div>1<br/>H<br/>hydrogen<br/>1.0</div>                        |                         |                       |                          |                         |                          |                        |                          |                       |                        |                         |                         |                         |                          |                        |                       |  |  |
| 3                      | 4                       | atomic number<br>atomic symbol<br>name<br>relative atomic mass |                         |                       |                          |                         |                          |                        |                          |                       |                        | 5                       | 6                       | 7                       | 8                        | 9                      |                       |  |  |
| Li<br>lithium<br>6.9   | Be<br>beryllium<br>9.0  |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        | B<br>boron<br>10.8      | C<br>carbon<br>12.0     | N<br>nitrogen<br>14.0   | O<br>oxygen<br>16.0      | F<br>fluorine<br>19.0  | Ne<br>neon<br>20.2    |  |  |
| 11                     | 12                      |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        | 13                      | 14                      | 15                      | 16                       | 17                     | 18                    |  |  |
| Na<br>sodium<br>23.0   | Mg<br>magnesium<br>24.3 |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        | Al<br>aluminium<br>27.0 | Si<br>silicon<br>28.1   | P<br>phosphorus<br>31.0 | S<br>sulfur<br>32.1      | Cl<br>chlorine<br>35.5 | Ar<br>argon<br>39.9   |  |  |
| 19                     | 20                      | 21                                                             | 22                      | 23                    | 24                       | 25                      | 26                       | 27                     | 28                       | 29                    | 30                     | 31                      | 32                      | 33                      | 34                       | 35                     | 36                    |  |  |
| K<br>potassium<br>39.1 | Ca<br>calcium<br>40.1   | Sc<br>scandium<br>45.0                                         | Ti<br>titanium<br>47.9  | V<br>vanadium<br>50.9 | Cr<br>chromium<br>52.0   | Mn<br>manganese<br>54.9 | Fe<br>iron<br>55.8       | Co<br>cobalt<br>58.9   | Ni<br>nickel<br>58.7     | Cu<br>copper<br>63.5  | Zn<br>zinc<br>65.4     | Ga<br>gallium<br>69.7   | Ge<br>germanium<br>72.6 | As<br>arsenic<br>74.9   | Se<br>selenium<br>79.0   | Br<br>bromine<br>79.9  | Kr<br>krypton<br>83.8 |  |  |
| 37                     | 38                      | 39                                                             | 40                      | 41                    | 42                       | 43                      | 44                       | 45                     | 46                       | 47                    | 48                     | 49                      | 50                      | 51                      | 52                       | 53                     | 54                    |  |  |
| Rb<br>rubidium<br>85.5 | Sr<br>strontium<br>87.6 | Y<br>yttrium<br>88.9                                           | Zr<br>zirconium<br>91.2 | Nb<br>niobium<br>92.9 | Mo<br>molybdenum<br>95.9 | Tc<br>technetium<br>—   | Ru<br>ruthenium<br>101.1 | Rh<br>rhodium<br>102.9 | Pd<br>palladium<br>106.4 | Ag<br>silver<br>107.9 | Cd<br>cadmium<br>112.4 | In<br>indium<br>114.8   | Sn<br>tin<br>118.7      | Sb<br>antimony<br>121.8 | Te<br>tellurium<br>127.6 | I<br>iodine<br>126.9   | Xe<br>xenon<br>131.3  |  |  |
| 55                     | 56                      | 57–71<br>lanthanoids                                           | 72                      | 73                    | 74                       | 75                      | 76                       | 77                     | 78                       | 79                    | 80                     | 81                      | 82                      | 83                      | 84                       | 85                     | 86                    |  |  |
| Cs<br>caesium<br>132.9 | Ba<br>barium<br>137.3   |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        | Tl<br>thallium<br>204.4 | Pb<br>lead<br>207.2     | Bi<br>bismuth<br>209.0  | Po<br>polonium<br>—      | At<br>astatine<br>—    | Rn<br>radon<br>—      |  |  |
| 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>—    | Ra<br>radium<br>—       |                                                                |                         |                       |                          |                         |                          |                        |                          |                       |                        | Nh<br>nihonium<br>—     | Fl<br>flerovium<br>—    | Mc<br>moscovium<br>—    | Lv<br>livermorium<br>—   | Ts<br>tennessine<br>—  | Og<br>oganesson<br>—  |  |  |

lanthanoids

actinoids

|           |         |              |           |            |           |           |            |           |             |             |         |              |           |            |
|-----------|---------|--------------|-----------|------------|-----------|-----------|------------|-----------|-------------|-------------|---------|--------------|-----------|------------|
| 57        | 58      | 59           | 60        | 61         | 62        | 63        | 64         | 65        | 66          | 67          | 68      | 69           | 70        | 71         |
| La        | Ce      | Pr           | Nd        | Pm         | Sm        | Eu        | Gd         | Tb        | Dy          | Ho          | Er      | Tm           | Yb        | Lu         |
| lanthanum | cerium  | praseodymium | neodymium | promethium | samarium  | europlum  | gadolinium | terbium   | dysprosium  | holmium     | erbium  | thulium      | ytterbium | lutetium   |
| 138.9     | 140.1   | 140.9        | 144.2     | —          | 150.4     | 152.0     | 157.3      | 158.9     | 162.5       | 164.9       | 167.3   | 168.9        | 173.1     | 175.0      |
| 89        | 90      | 91           | 92        | 93         | 94        | 95        | 96         | 97        | 98          | 99          | 100     | 101          | 102       | 103        |
| Ac        | Th      | Pa           | U         | Np         | Pu        | Am        | Cm         | Bk        | Cf          | Es          | Fm      | Md           | No        | Lr         |
| actinium  | thorium | protactinium | uranium   | neptunium  | plutonium | americium | curium     | berkelium | californium | einsteinium | fermium | mendeleevium | nobelium  | lawrencium |
| —         | 232.0   | 231.0        | 238.0     | —          | —         | —         | —          | —         | —           | —           | —       | —            | —         | —          |

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