



Cambridge International AS & A Level

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CHEMISTRY

9701/24

Paper 2 AS Level Structured Questions

May/June 2026

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. Do **not** use correction fluid or tape.
- 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.

- 1 Aluminium is a Group 13 element that forms a number of compounds.

Table 1.1

atom or ion	number of protons	number of neutrons
^{27}Al		
$^{28}\text{Al}^{3+}$		

- (a) (i) Complete Table 1.1 to show the number of particles in each atom or ion. [2]
- (ii) Complete Figure 1.1 to show the electronic configuration of an aluminium atom.

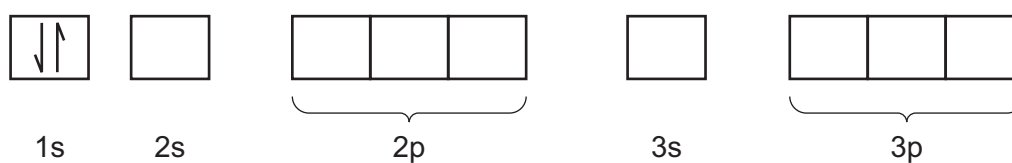


Figure 1.1

- (b) Deduce the formula of aluminium nitrate(V).

..... [1]

- (c) AlCl_3 dimerises to form Al_2Cl_6 . Al_2Cl_6 is shown in Figure 1.2.

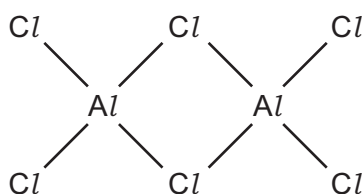


Figure 1.2

Describe how coordinate (dative covalent) bonds form when two AlCl_3 molecules combine to form Al_2Cl_6 .

..... [1]

.....



- (d) Aluminium forms the AlCl_4^- ion. The dot-and-cross diagram for AlCl_4^- in Figure 1.3 shows the arrangement of outer electrons.

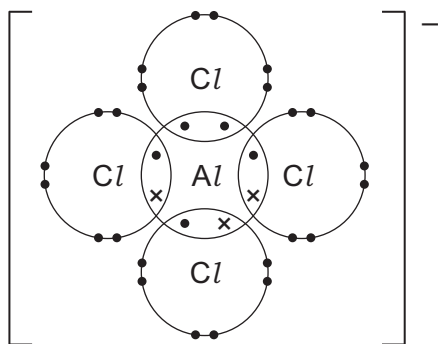


Figure 1.3

- (i) Use Figure 1.3 and VSEPR theory to name the shape of the AlCl_4^- ion and to predict the $\text{Cl}-\text{Al}-\text{Cl}$ bond angle.

name of shape

bond angle

[2]

- (ii) Draw the three-dimensional shape of the AlCl_4^- ion.

[1]

[Total: 8]

- 2 (a) (i) Nitrogen, N_2 , contains sigma (σ) and pi (π) bonds.

Describe how a pi (π) bond is formed.

.....

 [2]

- (ii) Explain the lack of reactivity of nitrogen.

.....

 [2]

- (b) Nitrogen is used to manufacture ammonia, NH_3 , in the Haber process. An iron catalyst is used.

- (i) Complete the reaction pathway diagram in Figure 2.1 to show the effect of adding an iron catalyst to the reaction of nitrogen and hydrogen.

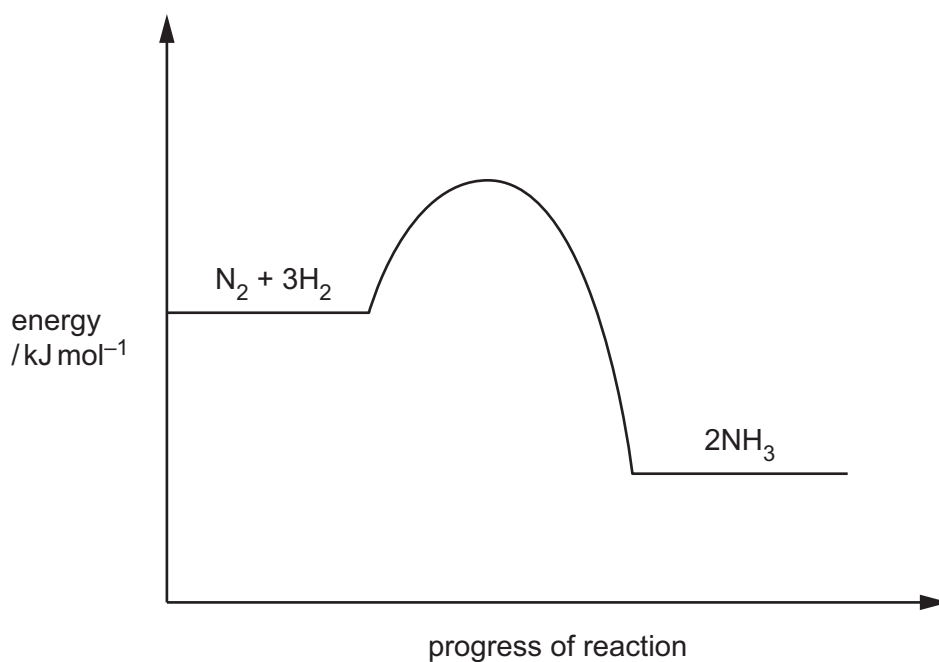


Figure 2.1

[1]

- (ii) State the temperature and pressure used in the Haber process.

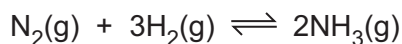
temperature =

pressure =

[2]



(c) The equation for the Haber process is shown.



Three separate experiments are carried out using mixtures of $\text{N}_2(\text{g})$ and $\text{H}_2(\text{g})$ to find the amount of $\text{NH}_3(\text{g})$ produced at equilibria under different conditions.

- (i) In experiment 1, 3.55 mol of $\text{N}_2(\text{g})$ and 8.60 mol of $\text{H}_2(\text{g})$ are mixed and left to reach equilibrium.

At equilibrium, 3.24 mol of NH_3 is present.

Complete Table 2.1.

Table 2.1

	$\text{N}_2(\text{g})$	$\text{H}_2(\text{g})$	$\text{NH}_3(\text{g})$
initial amount/mol	3.55	8.60	0
change in amount/mol			3.24
amount at equilibrium/mol			3.24

[3]

- (ii) In experiment 2, under different conditions $\text{N}_2(\text{g})$ and $\text{H}_2(\text{g})$ are mixed and left to reach equilibrium.

Table 2.2 shows the amount, in mol, at equilibrium of $\text{N}_2(\text{g})$, $\text{H}_2(\text{g})$ and $\text{NH}_3(\text{g})$.

Table 2.2

	$\text{N}_2(\text{g})$	$\text{H}_2(\text{g})$	$\text{NH}_3(\text{g})$
amount at equilibrium/mol	0.874	1.340	0.347

Calculate the mole fraction of $\text{NH}_3(\text{g})$ in the equilibrium mixture in experiment 2.

mole fraction of $\text{NH}_3(\text{g})$ = [2]

- (iii) The expression for the equilibrium constant, K_p , for the Haber process is shown.

$$K_p = \frac{p(\text{NH}_3)^2}{p(\text{N}_2) \times p(\text{H}_2)^3}$$

Describe what is meant by partial pressure.

.....

 [1]

- (iv) In experiment 3, the mixture at equilibrium contains the following partial pressures of $\text{N}_2(\text{g})$ and $\text{H}_2(\text{g})$.

$$p(\text{N}_2) = 1590 \text{ kPa}$$

$$p(\text{H}_2) = 1750 \text{ kPa}$$

For experiment 3, the equilibrium constant, K_p , is $8.49 \times 10^{-7} \text{ kPa}^{-2}$.

Calculate the partial pressure, in kPa, of $\text{NH}_3(\text{g})$ at equilibrium.

$$p(\text{NH}_3) = \dots\dots\dots \text{ kPa} \quad [3]$$



(d) Explain the effect of increasing temperature on rate of reaction.

.....

.....

.....

..... [3]

(e) Figure 2.2 shows the Boltzmann distribution for a sample of X(g) at temperature T_1 .

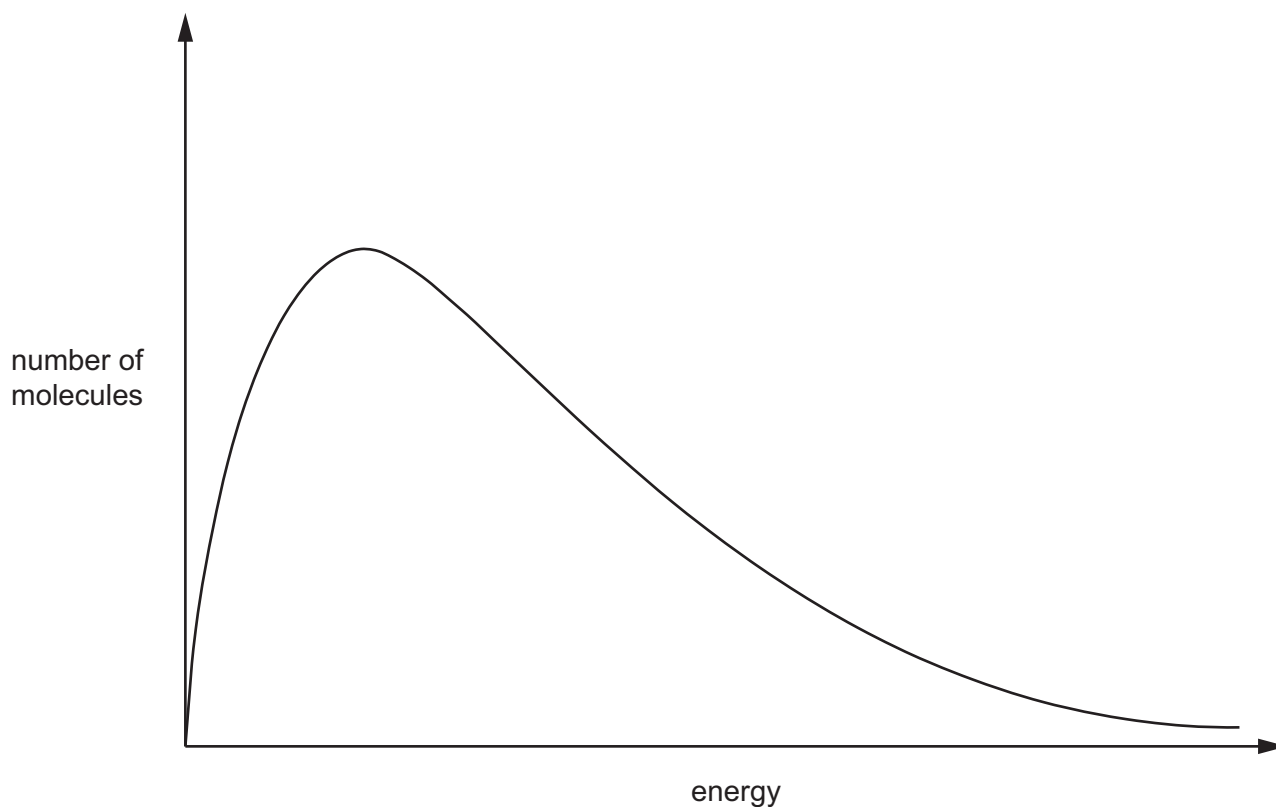


Figure 2.2

Sketch a curve on Figure 2.2 to show the Boltzmann distribution for the sample of X(g) at a temperature higher than T_1 . [2]

[Total: 21]

- 3 (a) (i) State the trend in atomic radius of the elements across Period 3.

..... [1]

- (ii) State the formula of the oxide formed when sodium reacts with oxygen.

..... [1]

- (iii) Write an equation for the reaction of MgO with water.

..... [1]

- (b) Table 3.1 shows some of the physical properties of Period 3 chlorides.

Table 3.1

	melting point /°C	boiling point /°C	type of bonding	type of structure
NaCl	801	1413		
SiCl₄	−69	58		

- (i) Complete Table 3.1 using the abbreviations shown.

M = metallic
C = covalent
I = ionic
S = simple
G = giant

[2]

- (ii) State the formula of the phosphorus-containing product formed when PCl_5 reacts with an excess of water. Suggest the pH of the resulting solution.

formula =

pH of solution =

[2]

- (c) (i) Describe what is observed when white solid strontium nitrate decomposes on heating.

..... [1]

- (ii) State the trend in solubility down the Group 2 hydroxides.

..... [1]

[Total: 9]



- 4 (a) Alcohol **S** has the structural formula $\text{CH}_3\text{C}(\text{OH})(\text{CH}_3)\text{CH}_2\text{CH}_3$.

Classify alcohol **S**.

..... [1]

- (b) Figure 4.1 shows compound **T**.

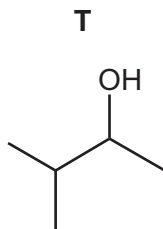


Figure 4.1

Tests are carried out on **T** using different reagents.

Complete Table 4.1 to show the observations of each test on **T**. If no reaction occurs, write 'no reaction' in the relevant box.

Table 4.1

reagent	observations
Na	
acidified $\text{K}_2\text{Cr}_2\text{O}_7$	
alkaline $\text{I}_2(\text{aq})$	

[3]

(c) Compound **W** is an aliphatic primary alcohol.

W is oxidised by acidified KMnO_4 when heated under reflux. Figure 4.2 shows the infrared spectrum of the resulting product.

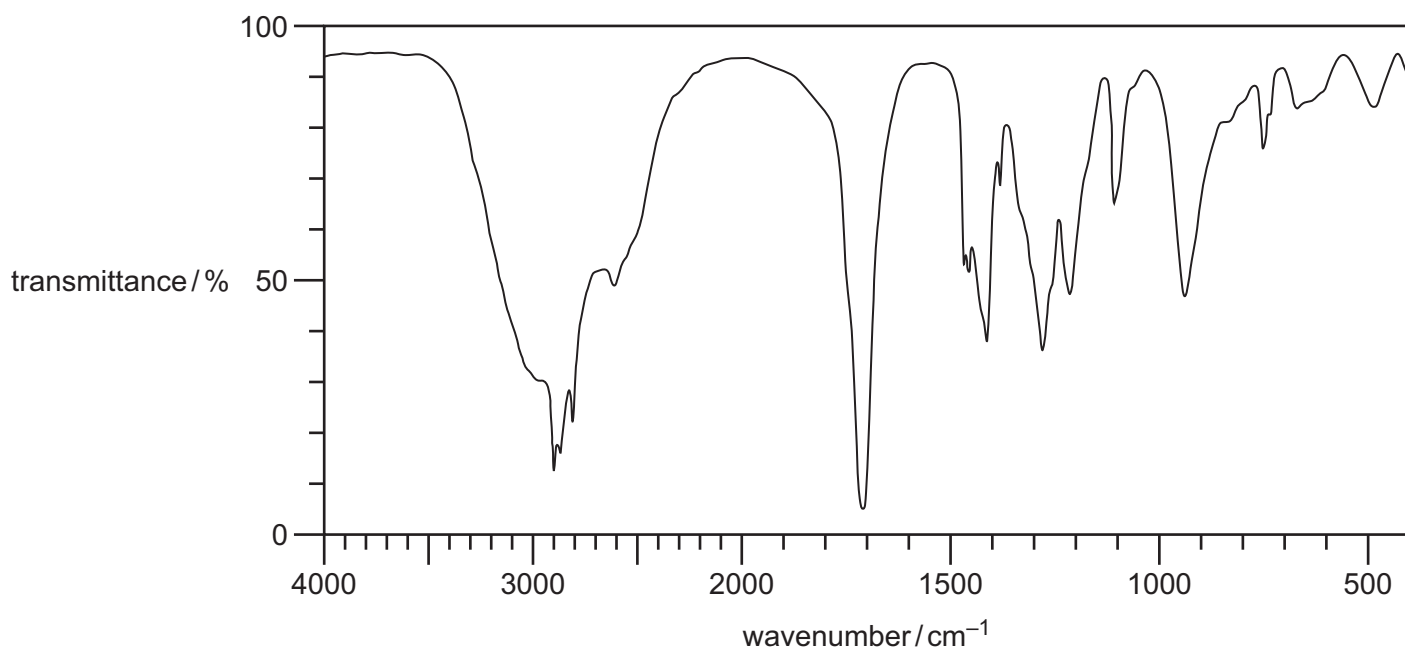


Figure 4.2

Table 4.2

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers)/ cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl, carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650



The infrared spectrum in Figure 4.2 confirms that **W** is a primary alcohol.

Use Figure 4.2 to identify **two** absorbances that confirm **W** is a primary alcohol. State the bond and functional group containing the bond for each absorbance.

.....

.....

..... [2]

(d) Butane is converted to pentanenitrile via a two-step synthesis, as shown in Figure 4.3.

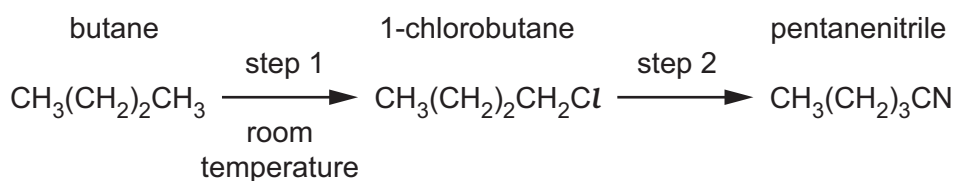


Figure 4.3

(i) Suggest the reagent and conditions for each step in Figure 4.3.

step 1

step 2 [2]

(ii) Pentanenitrile reacts with dilute acid.

Draw the displayed formula of the organic product made in this reaction.

[1]

[Total: 9]

5 Long-chain alkanes from crude oil can be cracked to make alkenes.

(a) State the conditions used for the cracking of alkanes.

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

(b) Propene is an alkene that is made by cracking. Alkenes are used in addition polymerisation.

(i) Draw **one** repeat unit of the addition polymer formed from propene.

[1]

(ii) The disposal of poly(alkenes) by combustion produces harmful products.

State **one** other disadvantage associated with the disposal of poly(alkenes) such as poly(propene).

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

(iii) Aqueous bromine is used to test for the presence of the C=C bond in propene.

State what is observed when aqueous bromine is mixed with propene.

..... [1]

(c) But-1-ene and but-2-ene are structural isomers.

State the type of structural isomerism shown by but-1-ene and but-2-ene.

..... [1]



(d) But-2-ene reacts with HBr(g) . The HBr acts as an electrophile in the reaction.

(i) State how HBr acts as an electrophile in terms of electron transfer.

..... [1]

(ii) Complete Figure 5.1 to show the mechanism for the reaction of but-2-ene with HBr .

Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



Figure 5.1

[4]

(e) But-1-ene and bromine, Br_2 , react in an electrophilic addition reaction to make product **P**.

Give the systematic name for **P**.

..... [1]



(f) Figure 5.2 shows the structure of methylpropene.

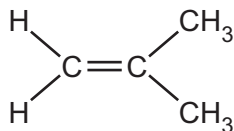
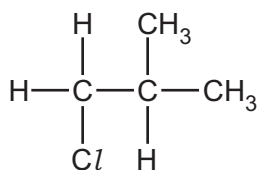


Figure 5.2

Methylpropene reacts with HCl to produce products **Q** and **R**.

Q



R

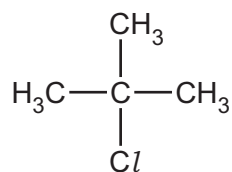


Figure 5.3

Explain why **R** is the major product in this reaction.

.....

.....

.....

..... [2]

[Total: 13]





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	$L = 6.022 \times 10^{23} \text{ mol}^{-1}$
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) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ 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 ⁻¹ K ⁻¹)

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The Periodic Table of Elements

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