Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME								
CENTRE NUMBER						CANDIDATE NUMBER		

CHEMISTRY **9701/43**

Paper 4 A Level Structured Questions **October/November 2025**

2 hours

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 100.
- 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 **28** pages. Any blank pages are indicated.

DC (CE/JG) 342071/3

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1 **(a)** Solutions of Group 2 hydrogencarbonates, $M(HCO_3)_2$, decompose on heating to give the corresponding metal carbonate, carbon dioxide and water.

(i) Write an equation for the decomposition of strontium hydrogencarbonate, $Sr(HCO_3)_2$.

.... [1]

(ii) The thermal stability of Group 2 carbonates increases down the group.

Explain this trend.

....

....

....

.... [2]

(b) The hydroxides and fluorides of Group 2 elements show similar trends in solubility.

Describe the trend in the solubility of the fluorides of calcium, strontium and barium.

Explain your answer.

....	....	....
least soluble		most soluble

explanation ....

....

....

....

....

....

.... [4]

(c) **(i)** Define enthalpy change of hydration, ΔH_{hyd}.

....

....

.... [1]

(ii) State the main factors that affect the magnitude of enthalpy change of hydration.

Explain your answer.

....

....

....

.... [2]

(d) Table 1.1 shows various energy changes.

Table 1.1

energy change	value / kJ mol^{-1}
lattice energy of MgF_2	–2957
enthalpy change of hydration, ΔH_{hyd}, of Mg^{2+}	–1926
enthalpy change of hydration, ΔH_{hyd}, of F^-	–505

Use data from Table 1.1 to calculate the enthalpy change of solution, ΔH_{sol}, for MgF_2(s).

It may be helpful to draw a labelled energy cycle. Show your working.

ΔH_{sol} of MgF_2(s) = ... kJ mol^{-1} [2]

(e) Mercury(I) fluoride, Hg_2F_2, is sparingly soluble in water.

The cation in Hg_2F_2 exists as the diatomic ion Hg_2^{2+} with a covalent Hg–Hg bond.

(i) Write the expression for the solubility product, K_{sp}, of Hg_2F_2. Include the units.

K_{sp} =

units ....
[2]

(ii) The solubility of Hg_2F_2 is $9.20 \times 10^{-3}\,\text{mol dm}^{-3}$ at 298 K.

Calculate the value of K_{sp} of Hg_2F_2 at 298 K.

K_{sp} = ... [1]

[Total: 15]

2 **(a)** Iron can form stable ions in the +2 and +3 oxidation states.

Explain why transition elements have variable oxidation states.

....

.... [1]

(b) Aqueous solutions of iron(II) salts contain the complex ion $[Fe(H_2O)_6]^{2+}$.

Define complex ion.

....

.... [1]

(c) $[Fe(H_2O)_6]^{2+}$ can be converted into $[Fe(H_2O)_4(OH)_2]$.

(i) Suggest a suitable reagent for this conversion. State the type of reaction.

reagent ....

type of reaction ....
[1]

(ii) $[Fe(H_2O)_4(OH)_2]$ is a green precipitate that turns brown on standing in air.

Table 2.1 shows electrode potentials for some electrode reactions.

Table 2.1

electrode reaction	$E^{\ominus}$ /V
$Fe(H_2O)_3(OH)_3 + H_2O + e^- \rightleftharpoons Fe(H_2O)_4(OH)_2 + OH^-$	–0.56
$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	+0.40

Use the information in Table 2.1 to explain why $[Fe(H_2O)_4(OH)_2]$ turns brown on standing in air.
Include an equation for this reaction.

....

....

....

....

....

.... [3]

(d) The complex $[Co(NH_3)_6]^{2+}$ reacts with hydrogen peroxide as shown.

reaction 1 $2[Co(NH_3)_6]^{2+} + H_2O_2 \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$ $E^{\ominus}_{cell} = +1.67\,V$

Calculate $\Delta G^{\ominus}$, in $kJ\,mol^{-1}$, for reaction 1.

$\Delta G^{\ominus}$ = ... $kJ\,mol^{-1}$ [2]

[Total: 8]

3 **(a)** Solid manganese(IV) oxide, MnO_2, catalyses the decomposition of hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

State the type of catalysis for this reaction. Explain your answer.

....

.... [1]

(b) Hydrogen peroxide reacts with iodide ions in acidic conditions as shown.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The initial rate of this reaction is investigated with different concentrations of H_2O_2, I^- and H^+. The results obtained are shown in Table 3.1.

Table 3.1

experiment	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	0.0450	0.0300	0.0125	2.42×10^{-3}
2	0.0225	0.0600	0.0125	2.42×10^{-3}
3	0.0225	0.120	0.0125	4.84×10^{-3}
4	0.0450	0.120	0.0500	9.68×10^{-3}

(i) Use the information in Table 3.1 to deduce the rate equation for this reaction.

Explain your reasoning.

....

....

....

....

....

....

.... [4]

(ii) Use your rate equation from **(b)(i)** and the data from Experiment 1 to calculate the rate constant, *k*, for this reaction. Include the units of *k*.

k = ... units .... [2]

(c) The rate of the thermal decomposition of azomethane, $CH_3N{=}NCH_3$, is investigated.

$$CH_3N{=}NCH_3 \rightarrow N_2 + C_2H_6$$

Fig. 3.1 shows the results obtained. The reaction is first order with respect to $CH_3N{=}NCH_3$.

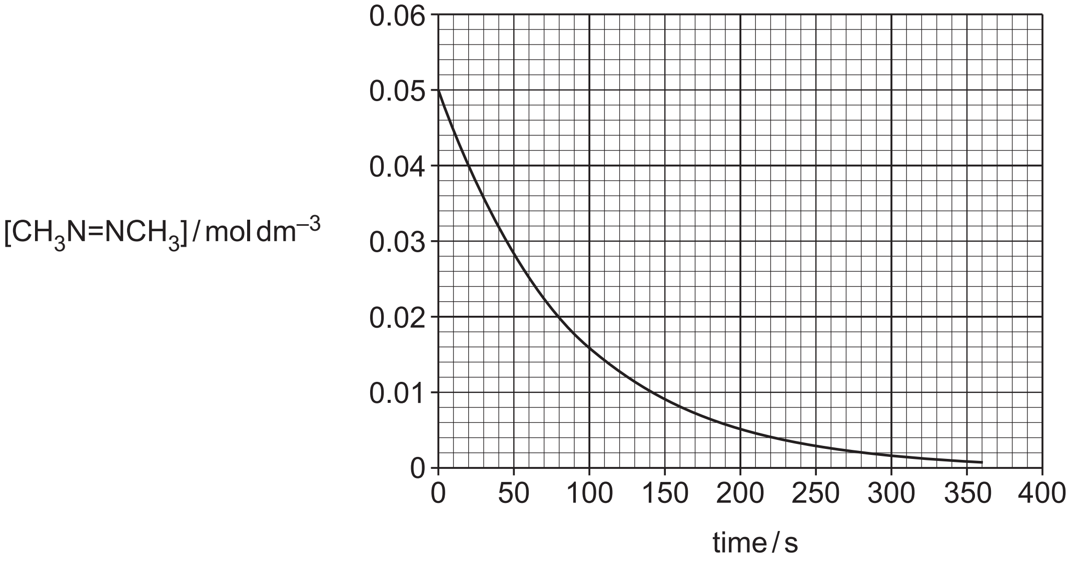


Fig. 3.1

(i) Use Fig. 3.1 to calculate **two** half-lives, $t_{\frac{1}{2}}$, to show that the reaction is first order.

....

....

....

.... [2]

(ii) Use your answer to **(c)(i)** to calculate the rate constant, *k*, for the decomposition of azomethane.

k = ... s^{-1} [1]

(d) Describe the effect of increasing temperature on the rate constant and on the rate of a reaction.

....

....

.... [1]

[Total: 11]

4 **(a)** Define standard cell potential, $E^{\ominus}_{\text{cell}}$. Include a description of standard conditions.

....

....

.... [2]

(b) The Daniell cell is an electrochemical cell consisting of a $Cu^{2+}(aq)/Cu(s)$ electrode and a $Zn^{2+}(aq)/Zn(s)$ electrode.

(i) Draw a labelled diagram of this electrochemical cell.

Include all necessary substances and relevant pieces of apparatus needed to measure the $E^{\ominus}_{\text{cell}}$.

It is **not** necessary to state the conditions used.

[3]

(ii) State the charge carriers that transfer current through the solutions and through the wire.

the solutions .... the wire .... [1]

(iii) The standard electrode potential, $E^{\ominus}$, for the $Zn^{2+}(aq)/Zn(s)$ electrode is –0.76 V.

Water is added to a standard $Zn^{2+}(aq)/Zn(s)$ electrode.

The new concentration of $Zn^{2+}(aq)$ is $0.25\,mol\,dm^{-3}$.

Use the Nernst equation to calculate the electrode potential, E, for this new $Zn^{2+}(aq)/Zn(s)$ electrode.

$E\,(Zn^{2+}(aq)/Zn(s))$ = ... V [2]

(c) An electrochemical cell consists of a ZnO/Zn electrode and a MnO_2/Mn_2O_3 electrode in an alkaline electrolyte.

The standard cell potential, $E^{\ominus}_{cell}$, for this cell is +1.47 V.

The half-equation at each electrode when this cell is discharging is shown.

$$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$$

$$2MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2OH^-$$

(i) Use this information to determine the change in oxidation state of manganese when this cell is discharging.

from .... to .... [1]

(ii) Write the equation for the overall reaction that occurs when this cell is discharging.

.... [1]

(iii) The $E^{\ominus}$ for the ZnO/Zn electrode is –1.28 V.

Calculate the standard electrode potential, $E^{\ominus}$, for the MnO_2/Mn_2O_3 electrode.

$E^{\ominus}$ (MnO_2/Mn_2O_3) = ... V [1]

[Total: 11]

5 **(a)** Copper shows typical properties of transition elements, including its behaviour as a catalyst.

Complete Table 5.1 to show the total number of **unpaired** electrons in the 3d and 4s orbitals of an isolated gaseous Cu atom and a Cu^{2+} ion.

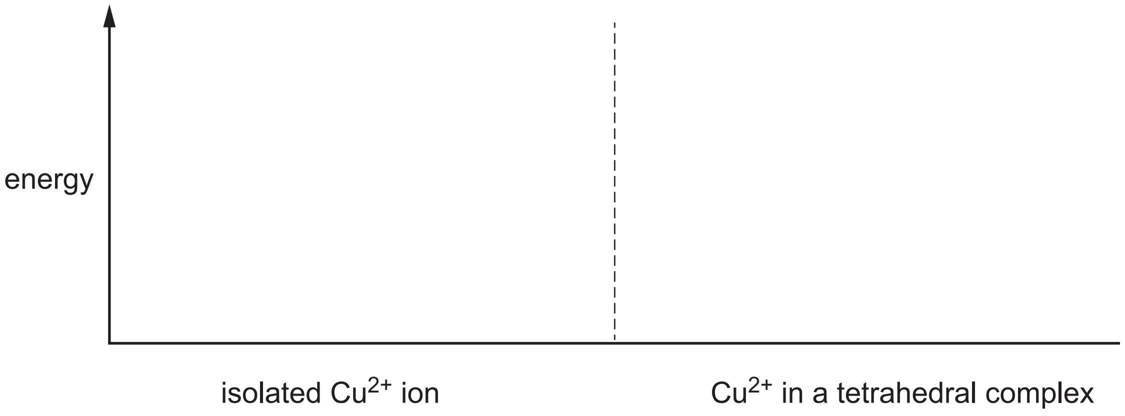
Table 5.1

species	number of **unpaired** electrons	
	3d	4s
Cu		
Cu^{2+}		

[1]

(b) The 3d orbitals in an isolated Cu^{2+} ion are degenerate.

Complete the diagram to show the relative energies of the 3d orbitals in an isolated Cu^{2+} ion and in Cu^{2+} in a tetrahedral complex.



[2]

(c) Explain why transition elements behave as catalysts.

....

....

.... [2]

(d) CN^- is a monodentate ligand.

Table 5.2 shows information about two complex ions that contain only CN^- ions as ligands.

Complete Table 5.2.

Table 5.2

metal ion	coordination number	formula of complex ion	charge of complex ion
Ag^+	2		
Fe^{2+}			4–

[2]

(e) The complex ion $[Au(CN)_2Br_2]^-$ displays geometrical (cis / trans) isomerism.

Draw the structure of *trans*-$[Au(CN)_2Br_2]^-$. State its shape and the Br-Au-Br bond angle.

shape ....

Br-Au-Br bond angle = ...

[2]

(f) An impure sample of a vanadium(V) compound of mass 0.250 g is dissolved in aqueous acid. This solution contains VO_3^- ions.

An excess of zinc is added to this solution. All the VO_3^- ions are reduced to V^{2+} ions and Zn atoms are oxidised to Zn^{2+} ions.

The unreacted zinc is removed and the resulting solution is titrated with acidified MnO_4^-.

The end-point is reached when 22.5 cm^3 of 0.0750 $mol\,dm^{-3}$ MnO_4^- is added.

A redox reaction takes place and all the V^{2+} reacts forming VO_3^-.

$$3MnO_4^- + 5V^{2+} + 3H_2O \rightarrow 3Mn^{2+} + 5VO_3^- + 6H^+$$

(i) Calculate the percentage by mass of vanadium in the 0.250 g of impure sample.

Assume the impurities do not contain any vanadium ions.

Show your working.

percentage of vanadium = ... [3]

(ii) Complete the equation for the reaction between acidified VO_3^- ions and Zn metal.

...... VO_3^- + ... Zn + ... → ...... V^{2+} + ... Zn^{2+} + ...

[2]

[Total: 14]

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6 **(a)** Thin-layer and gas / liquid chromatography can be used to separate mixtures into their individual components.

(i) Define the following terms used in chromatography.

R_f value ....

....

retention time ....

....

[2]

(ii) Each type of chromatography makes use of a stationary phase and a mobile phase.

Complete Table 6.1 with a description of each of these.

Table 6.1

	stationary phase	mobile phase
thin-layer chromatography	☒	
gas / liquid chromatography		☒

[1]

(b) A mixture of two substances **A** and **B** is analysed by thin-layer chromatography.

The R_f value of substance **A** is larger than that of substance **B**.

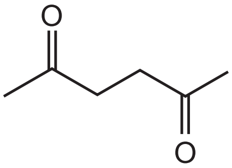
Suggest why substance **A** has a larger R_f value.

....

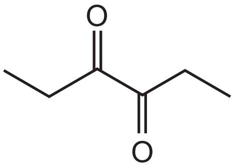
.... [1]

(c) The two isomeric compounds **Y** and **Z** are analysed by proton (^{1}H) NMR spectroscopy.

Y



Z



(i) Complete Table 6.2 to predict the number of peaks observed in the proton (^{1}H) NMR spectra for **Y** and **Z**.

Table 6.2

compound	number of peaks observed
Y	
Z	

[1]

(ii) Name **all** the different splitting patterns observed in the proton (^{1}H) NMR spectra for **Y** and **Z**.

Y ....

Z ....

[2]

[Total: 7]

7 **(a)** State the relative acidities of bromoethanoic acid, $BrCH_2COOH$, chloroethanoic acid, $\mathrm{C}l\mathrm{CH_2COOH}$, ethanoic acid, CH_3COOH and ethanol, CH_3CH_2OH.

Explain your answer.

....

most acidic least acidic

....

....

....

....

....

....

.... [4]

(b) Fig. 7.1 shows the reaction of methylbenzene and ethanedioic acid with $KMnO_4$.

Predict the major carbon-containing product for each of these reactions.

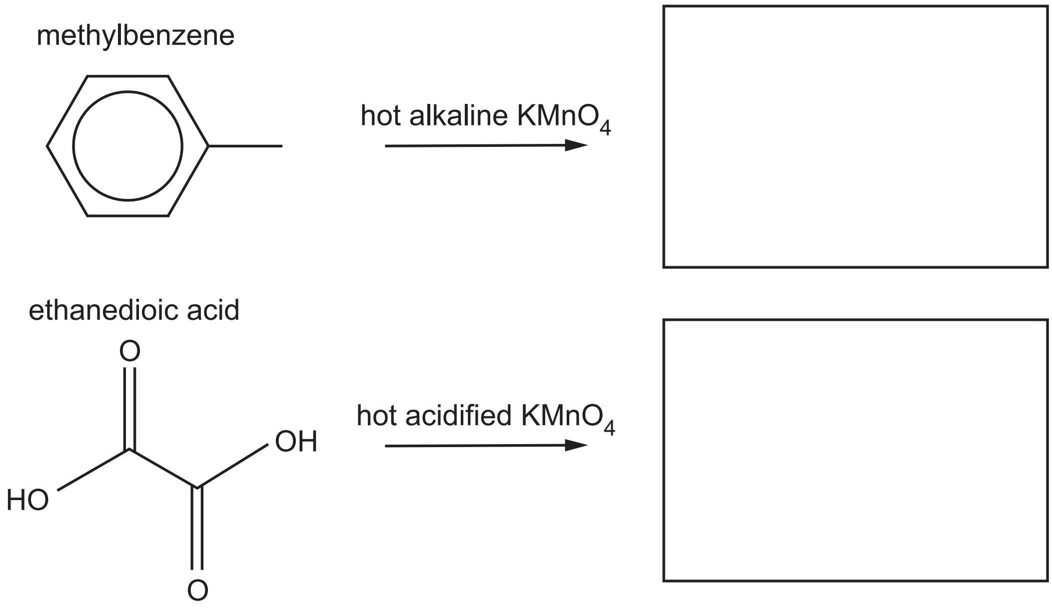
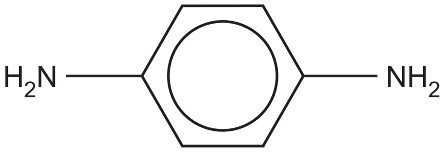


Fig. 7.1

[2]

(c) Polyamide **X** can be synthesised from ethanedioic acid and benzene-1,4-diamine.

benzene-1,4-diamine



(i) Draw the repeat unit of polyamide **X** in the box.

The new functional group formed should be shown displayed.

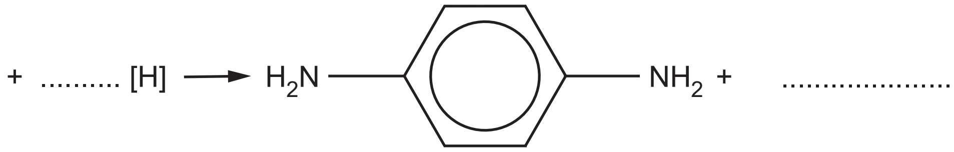
polyamide **X**

[2]

(ii) Benzene-1,4-diamine can be formed by reduction of 1,4-dinitrobenzene.

Complete the equation for this reduction.

[H] represents one atom of hydrogen from a reducing agent.



....

[1]

(d) Fig. 7.2 shows the two-step synthesis of the azo compound **W**.

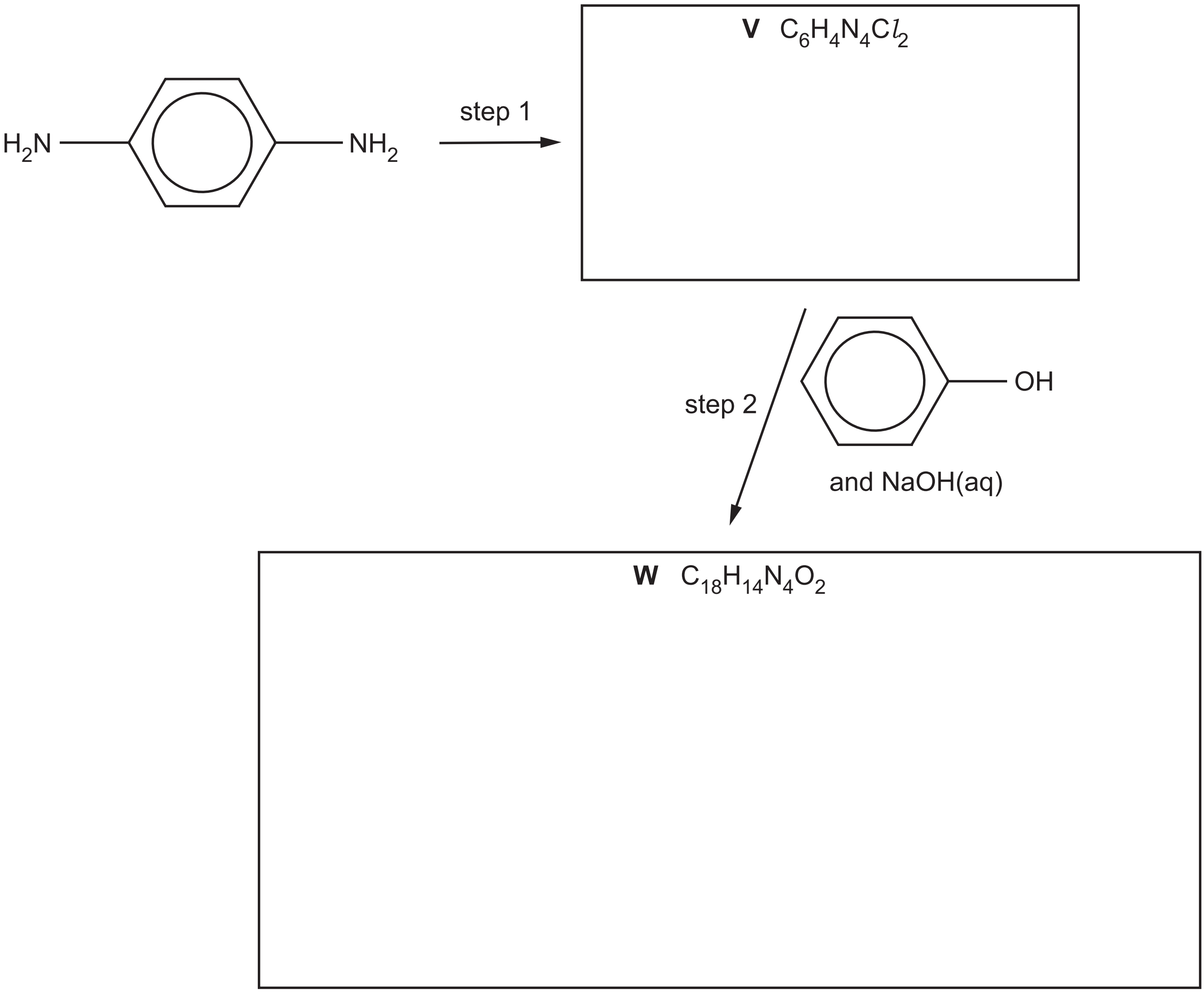


Fig. 7.2

(i) Suggest structures for compounds **V** and **W** and draw them in the boxes in Fig. 7.2. [2]

(ii) Give the reagents and conditions for step 1.

.... [1]

[Total: 12]

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8 **(a)** In the electrophilic substitution of arenes, different substituents can direct to different ring positions.

(i) Describe the directing effect of the $–NO_2$ group. Explain your answer.

....

.... [1]

(ii) The nitration of arenes uses a mixture of concentrated HNO_3 and concentrated H_2SO_4 to generate the NO_2^+ electrophile.

Write an equation for the formation of the NO_2^+ electrophile.

.... [1]

(b) Carbon-carbon bond formation is an important reaction in organic synthesis.

Fig. 8.1 shows the synthesis of compound **Q** from benzene in two reaction steps.

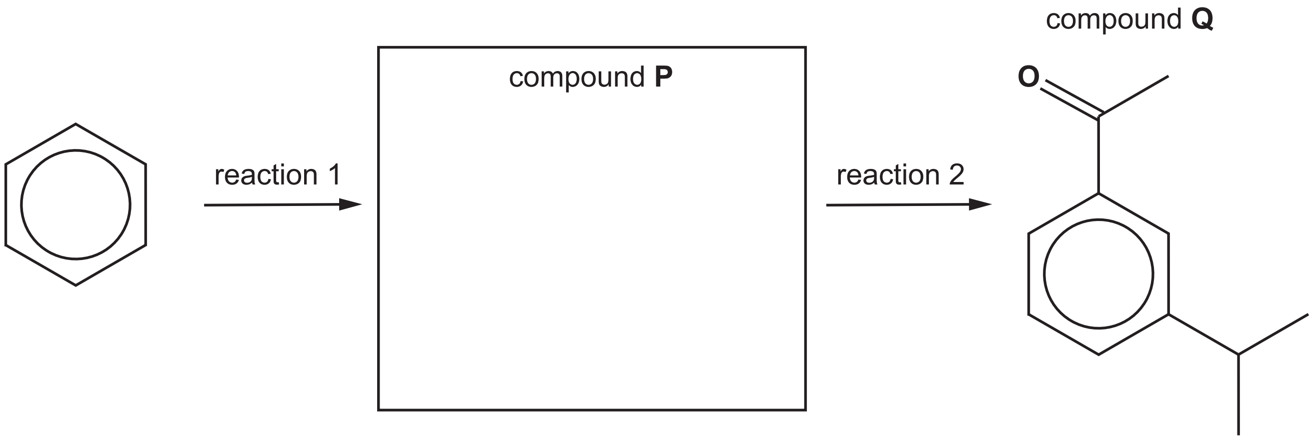


Fig. 8.1

(i) Draw the structure of compound **P** in the box in Fig. 8.1. [1]

(ii) Suggest reagents and conditions for reactions 1 and 2 in Fig. 8.1.

reaction 1 ....

reaction 2 ....

[2]

(c) Separate samples of C_6H_5Br and $C_6H_5CH_2Br$ are added to warm $AgNO_3(aq)$.

State the expected observations, if any. Explain your answer.

C_6H_5Br with $AgNO_3(aq)$ ....

$C_6H_5CH_2Br$ with $AgNO_3(aq)$ ....

explanation ....

....

....

.... [3]

(d) Acyl bromides, RCOBr, react readily with H_2O.

The mechanism of this reaction is similar to that of the reaction of H_2O with acyl chlorides, RCO*Cl*.

(i) Name the mechanism of this reaction.

.... [1]

(ii) Complete the mechanism in Fig. 8.2 for the reaction of RCOBr with H_2O.

Include all relevant lone pairs of electrons, curly arrows, charges and dipoles.

Draw the structure of the intermediate.

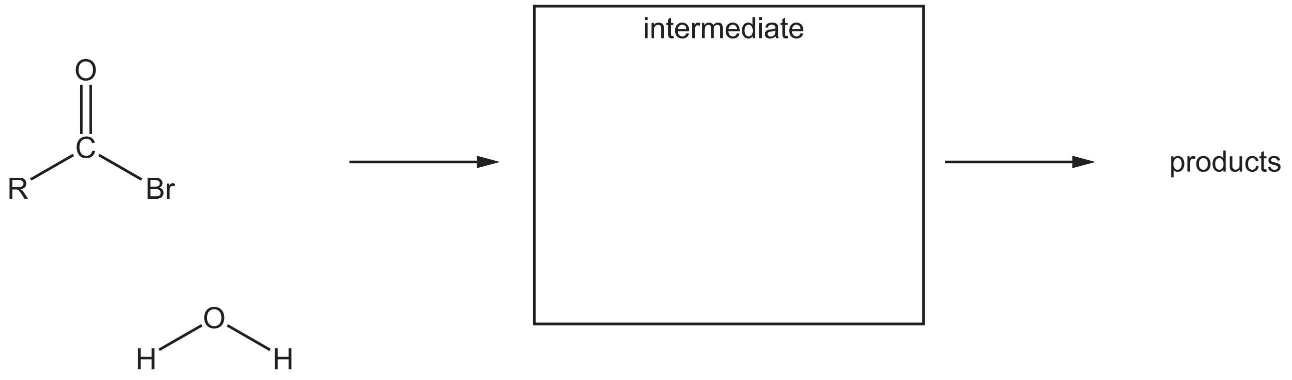


Fig. 8.2

[4]

[Total: 13]

9 **(a)** Explain why amides are much weaker bases than amines.

....

....

....

.... [2]

(b) Fig. 9.1 shows the preparation of 2-phenylethylamine, $C_6H_5CH_2CH_2NH_2$, by three different routes.

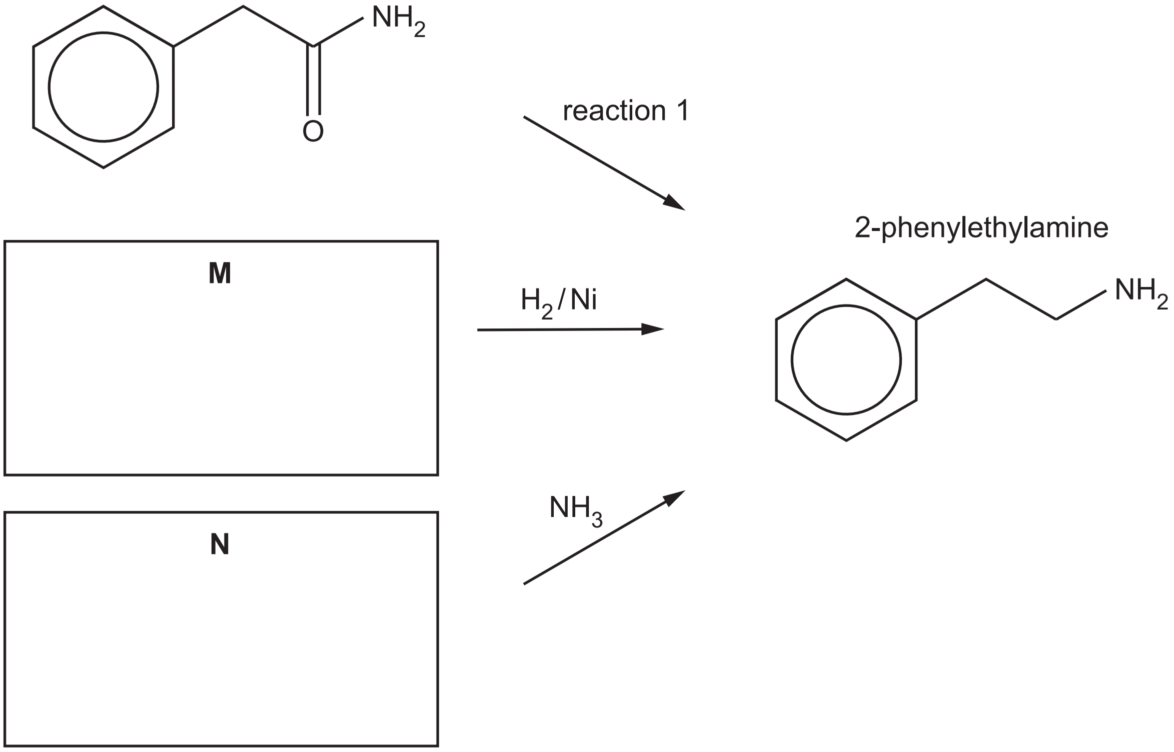


Fig. 9.1

(i) Suggest structures for compounds **M** and **N** and draw them in the boxes in Fig. 9.1. [2]

(ii) Give the reagents and conditions for reaction 1.

.... [1]

(c) Fig. 9.2 shows compound **H** which is a useful starting material in organic synthesis.

H

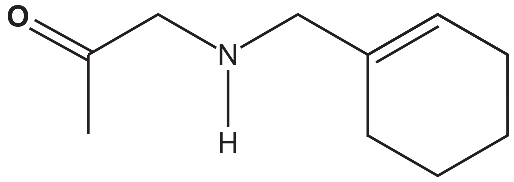


Fig. 9.2

H contains an alkene and an amine functional group.

Name the **other** functional group and give the classification of the amine group in **H**.

other functional group in **H** ....

classification of amine ....

[1]

(d) Ozonolysis involves the oxidative cleavage of a C=C bond in alkenes using ozone, O_3, as shown in Fig. 9.3.

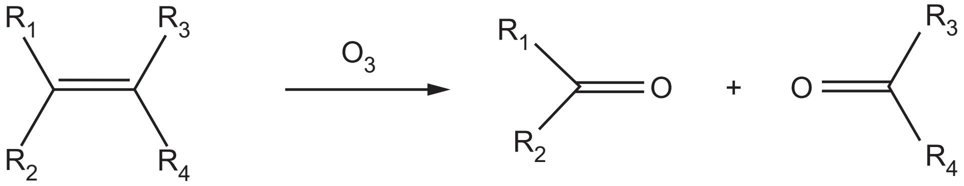


Fig. 9.3

Fig. 9.4 shows the first step in this reaction which involves the formation of an ozonide intermediate.

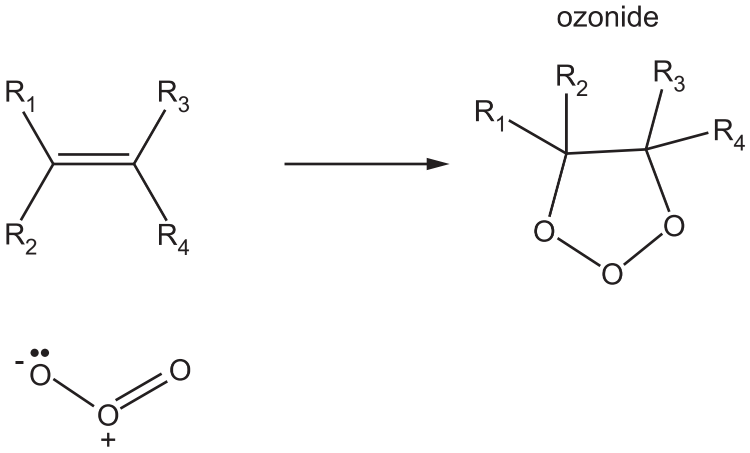
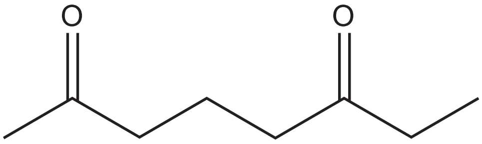


Fig. 9.4

(i) On Fig. 9.4, draw **three** curly arrows to complete the mechanism of this step. [2]

(ii) **L** is formed from alkene **K**, C_8H_{14}, by a similar reaction to that shown in Fig. 9.3.

L



Suggest the structure of **K**.

K C_8H_{14}

[1]

[Total: 9]

Important values, constants and standards

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

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group																	
1	2	3	4	5	6	7	8	9	10	11	12	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											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 –

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 –