Past Papers Advanced Higher Chemistry

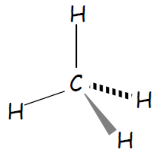
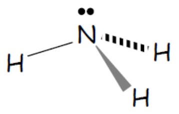
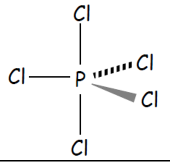
2023

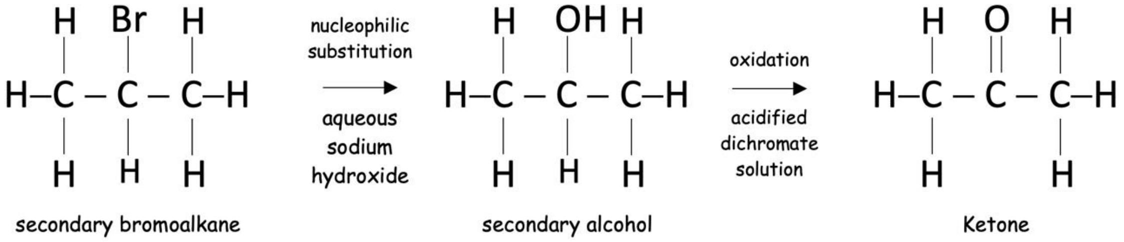
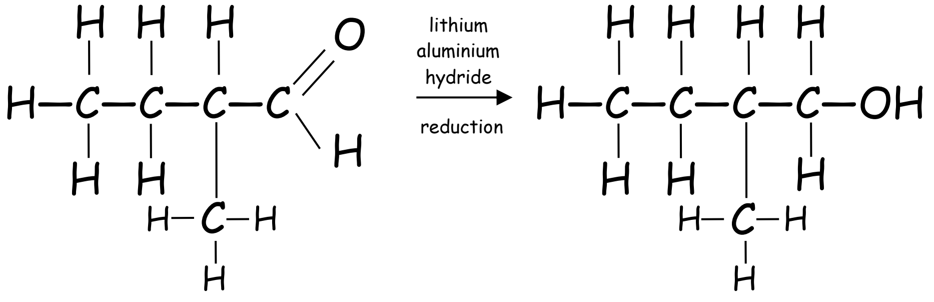
Marking Scheme

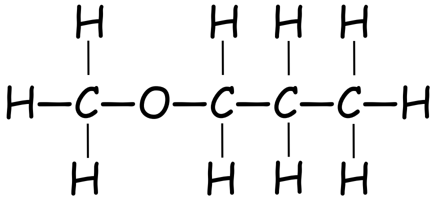
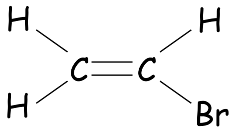
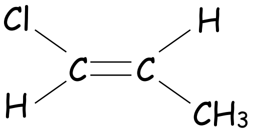
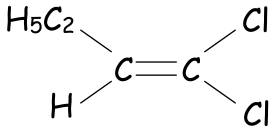
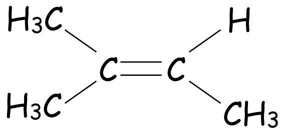
Grade Awarded	Mark Required		% candidates achieving grade
	(/120)	%	
A	77+	64.2%	27.2%
B	62+	51.7%	28.6%
C	48+	40.0%	22.8%
D	33+	27.5%	14.6%
No award	<33	<27.5%	6.7%

Section:	Multiple Choice	Extended Answer	Project
Average Mark:	15.7 /25	50.4 /95	No Project in 2023

2023 Adv Higher Chemistry Marking Scheme

<table>
<tr><th>MC Qu</th><th>Answer</th><th>% Correct</th><th>Reasoning</th></tr>
<tr><td>1</td><td>D</td><td>89</td><td>☒A Aufbau principle states that 4s fills before 3d shells
☒B Aufbau principle states that 4s fills before 3d shells
☒C $4s^1$ only occurs when 3d is either half-filled $3d^5$ in Cr or completely full $3d^{10}$ in Cu
☑D 4s is filled before 3d</td></tr>
<tr><td>2</td><td>C</td><td>68</td><td>
<table>
<tr><td colspan="2">Linear</td><td colspan="2">Tetrahedral</td><td colspan="2">Trigonal Pyramidal</td><td colspan="2">Trigonal Bipyramidal</td></tr>
<tr><td colspan="2">2
electron pairs</td><td colspan="2">4
electron pairs</td><td colspan="2">4
electron pairs</td><td colspan="2">5
electron pairs</td></tr>
<tr><td>2
bonding pairs</td><td>0
lone pairs</td><td>4
bonding pairs</td><td>0
lone pairs</td><td>3
bonding pairs</td><td>1
lone pairs</td><td>5
bonding pairs</td><td>0
lone pairs</td></tr>
<tr><td colspan="2">Cl — Be — Cl</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>
</td></tr>
<tr><td>3</td><td>B</td><td>95</td><td>☒A s-block found in groups 1+2
☑B p-block found in groups 3→0
☒C d-block forum in transition metals between groups 2+3
☒D f-block found in bottom 2 rows of Periodic Table</td></tr>
<tr><td>4</td><td>A</td><td>65</td><td>☑A Heterogeneous catalysis work by adsorption of reactants onto active sites of catalyst and homogeneous catalyst are in same state as catalysts.
☒B an incomplete d-subshell is required for the interaction of the catalyst with reactant(s)
☒C heterogeneous catalyst is in a different state to the reactants
☒D adsorption onto active siters is the mechanism of heterogeneous catalsyts</td></tr>
<tr><td>5</td><td>D</td><td>47</td><td>Halfway point of steep vertical region (neutralisation point) of line is approx. pH=6
☒A acidic pH at start of experiment ∴ alkali is being added to an acid
☒B strong alkali/weak acid gives alkaline pH on neutralisation but pH is acidic at neutralisation
☒C acidic pH at start of experiment ∴ alkali is being added to an acid
☑D pH at neutralisation is acidic weak alkali and strong acid gives acidic pH on neutralisation</td></tr>
<tr><td>6</td><td>D</td><td>69</td><td>
<table>
<tr><th>Term</th><th>Bronsted-Lowry Definition</th></tr>
<tr><td>acid</td><td>Species which donates H^+ and becomes conjugate base</td></tr>
<tr><td>base</td><td>Species which accepts H^+ and becomes conjugate acid</td></tr>
<tr><td>conjugate acid</td><td>Species formed when base accepted an H^+ ion</td></tr>
<tr><td>conjugate base</td><td>Species formed when acid donated an H^+ ion</td></tr>
</table>
H_3O^+ ions being absorbed by **conjugate base** turning back into acid
Weak acid donates H_3O^+ ions and becomes conjugate base in the process.</td></tr>
<tr><td>7</td><td>A</td><td>78</td><td>☑A reactions which are feasible have negative values of ΔG and equilibrium favours products
☒B a feasible reaction is one that tends towards the products rather than the reactants
☒C a reaction with a positive value for standard free energy (ΔG) is not feasible
☒D a reaction with a positive value for standard free energy (ΔG) is not feasible</td></tr>
<tr><td>8</td><td>B</td><td>46</td><td>❶ $\frac{1}{2}N_2 + O_2 \rightarrow NO_2$ $\Delta G^o = +51.8\ kJ\ mol^{-1}$
❷ $N_2 + 2O_2 \rightarrow N_2O_4$ $\Delta G^o = +97.7\ kJ\ mol^{-1}$
❶x-2 $2NO_2 \rightarrow N_2 + 2O_2$ $\Delta G^o = -103.6\ kJ\ mol^{-1}$
❷ $N_2 + 2O_2 \rightarrow N_2O_4$ $\Delta G^o = +97.7\ kJ\ mol^{-1}$
cancel out $2NO_2 \rightarrow \cancel{N_2} + \cancel{2O_2}$
$\cancel{N_2} + \cancel{2O_2} \rightarrow N_2O_4$ $\Delta G^o = -5.9 kJ\ mol^{-1}$
Final equation $2NO_2 \rightarrow N_2O_4$ $\Delta G^o = -5.9 kJ\ mol^{-1}$</td></tr>
</table>

9	C	55	Positive ΔS value means an increase in disorder. ☒A burning solid carbon into the gas CO_2 is an increase in disorder and exothermic ☒B water vapour turning into solid snowflakes is a decrease in disorder and exothermic ☑C liquid ethoxyethane (ether) evaporating into gas is endothermic and increases disorder ☒D two gases becoming one solid is a decrease in disorder and exothermic
10	A	76	Rate = k[X][Y] means that both X and Y are first order and 1 molecule of each appears as reactants in the slow rate determining step. ∴ X + Y → intermediate The overall reaction is X + 2Y → Z so there must be a second step where the intermediate formed in (slow) rate determining step reacts with a further molecule of Y.
11	A	77	The single carbon – carbon bond in alkanes is a sigma bond. Sigma bonds are formed by the **end-on overlap of atomic orbitals** along the axis of the covalent bond. In a non-polar covalent bond in an alkane, the bonding molecular orbital is **symmetrical** about the midpoint between two atoms. (Polar covalent bonds result from bonding molecular orbitals that are asymmetric about the midpoint between two atoms.)
12	C	87	☒A blue-green light is absorbed and not transmitted. Only red colour is transmitted. ☒B electrons move from HOMO to LUMO to absorb a wavelength of light ☑C electrons move from HOMO to LUMO and blue-green light absorbed and red transmitted ☒D electrons move from HOMO to LUMO to absorb a wavelength of light
13	D	87	☒A ethanol contains O-H bonds and has hydrogen bonding between molecules ☒B ethylamine contains N-H bonds and has hydrogen bonding between molecules ☒C ethanoic acid contains O-H bonds and has hydrogen bonding between molecules ☑D ethoxyethane has no N-H, O-H or H-F bonds and no hydrogen bonding in pure substance
14	A	70	
15	C	71	 2-methylbutanal 2-methylbutan-1-ol • $CH_3CH_2CH(CH_3)CHO$ is an aldehyde called 2-methylbutanal • $LiAlH_4$ is the reducing agent lithium aluminium hydride • Aldehydes are reduced to primary alcohols by $LiAlH_4$
16	B	63	$C_4H_8O_2 + NH_3 \rightarrow X \rightarrow Y + H_2O$ $C_4H_8O_2 + NH_3 \rightarrow C_4H_{11}NO_2 \rightarrow C_4H_9NO + H_2O$ ☒A $CH_3CH_2CH_2CN$ has a molecular formula of C_4H_7N ☑B $CH_3CH_2CH_2CONH_2$ has a molecular formula of C_4H_9NO ☒C $CH_3CH_2CH_2CH_2NH_2$ has a molecular formula of $C_4H_{11}N$ ☒D $CH_3CH_2CH_2COONH_2$ has a molecular formula of $C_4H_9NO_2$

<table>
<tr><td>17</td><td>A</td><td>87</td><td>Methoxypropane has the structure:

It has a molecular formula of $C_4H_{10}O$
☑A butanone $CH_3CH_2COCH_3$ has a molecular formula of C_4H_8O
☒B ethoxyethane $CH_3CH_2OCH_2CH_3$ has a molecular formula of $C_4H_{10}O$
☒C butan-2-ol $CH_3CH(OH)CH_2CH_3$ has a molecular formula of $C_4H_{10}O$
☒D 2-methylpropan-1-ol $CH_3CH(CH_3)CH_2OH$ has a molecular formula of $C_4H_{10}O$</td></tr>
<tr><td>18</td><td>B</td><td>49</td><td>
<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>CH_2CHBr</td><td>$CHClCHCH_3$</td><td>$CH_3CH_2CHCCl_2$</td><td>$CH_3C(CH_3)CHCH_3$</td></tr>
<tr><td>
bromoethane</td><td>
trans-1-chloropropene</td><td>
1,1-dichlorobut-1-ene</td><td>
2-methylbut-2-ene</td></tr>
<tr><td>Left end of C=C double bond has two H groups attached. This prevents it from being a geometric isomer</td><td>There are two (non-identical) groups, one on each end of the C=C double bond. This makes it a geometric isomer</td><td>Left end of C=C double bond has two H groups attached. This prevents it from being a geometric isomer</td><td>Left end of C=C double bond has two CH_3 groups attached. This prevents it from being a geometric isomer</td></tr>
</table>
</td></tr>
<tr><td>19</td><td>A</td><td>47</td><td>☑A in mass spectroscopy, the molecule breaks up during the process to give different lines
☒B in infrared spectroscopy, molecule has certain bonds stretched at certain wavenumbers
☒C in melting point analysis, a pure substance will melt first but will freeze back again.
☒D Proton NMR uses radio waves to flip nuclei but does not destroy the sample.</td></tr>
<tr><td>20</td><td>D</td><td>65</td><td>
<table>
<tr><th>Type of Drug</th><th>Binding Site</th><th>Response</th></tr>
<tr><td>Agonist</td><td>receptor binding site</td><td>produces a response similar to the body's natural response</td></tr>
<tr><td>Antagonist</td><td>receptor binding site</td><td>blocks the body's natural response</td></tr>
<tr><td>Enzyme Inhibitor</td><td>enzyme active site</td><td>blocks the action of the enzyme</td></tr>
</table>
</td></tr>
<tr><td>21</td><td>D</td><td>65</td><td>☒A As doxepin is only molecule with O atom at top, this part not in common fragment
☒B Molecule B is incorrect at bottom the nitrogen part is rotatory and will flip round
☒C Doxepin lacks the -Cl group on top left of molecule ∴ Cl not in common fragment
☑D Molecule D is correct as the nitrogen group is rotary & flips round and found in all drugs</td></tr>
<tr><td>22</td><td>B</td><td>87</td><td>
<table>
<tr><th>Element</th><th>V</th><th>O</th></tr>
<tr><td>Mass or %</td><td>61.4%</td><td>38.6</td></tr>
<tr><td>No. of moles
(divide % by gfm)</td><td>$\frac{61.4}{50.9}$ = 1.21</td><td>$\frac{38.6}{16}$ = 2.41</td></tr>
<tr><td>Mole ratio
(divide through by smallest value)</td><td>$\frac{1.21}{1.21}$ = 1</td><td>$\frac{2.41}{1.21}$ = 1.99 =2</td></tr>
<tr><td>Empirical Formula</td><td colspan="2">VO_2</td></tr>
</table>
</td></tr>
</table>

<table>
<tr>
<td>23</td>
<td>C</td>
<td>49</td>
<td>
A primary standard must:
<table>
<tr><td>be available in a high state of purity</td><td>be stable when solid and in solution</td><td>be soluble</td><td>have a reasonably high GFM</td></tr>
</table>
<table>
<tr><td>Examples of primary standards include:</td><td>sodium carbonate
Na_2CO_3</td><td>hydrated oxalic acid
$H_2C_2O_4{\cdot}2H_2O$</td><td>potassium hydrogen phthalate
$KH(C_8H_4O_4)$</td></tr>
<tr><td></td><td>silver nitrate
$AgNO_3$</td><td>potassium iodate
KIO_3</td><td>potassium dichromate
$K_2Cr_2O_7$</td></tr>
</table>
☒A calcium carbonate is insoluble and therefore not a primary standard
☒B Hydrochloric acid
☑C sodium carbonate meets the four criteria listed in table above
☒D Sodium hydroxide is not a primary standard as it has a relatively low GFM, is unstable as a solid (absorbs moisture) and unstable as a solution. Sodium hydroxide solution must be standardised before being used in volumetric analysis.
</td>
</tr>
<tr>
<td>24</td>
<td>B</td>
<td>61</td>
<td>
420 ppm = 420mg CO_2 per 1kg atmosphere
1kg atmosphere = 0.42g CO_2
5.1×10^{18}kg atmosphere = 0.42g CO_2 x 5.1×10^{18}
= 2.142×10^{18}g CO_2
= 2.1×10^{15}kg CO_2
</td>
</tr>
<tr>
<td>25</td>
<td>B</td>
<td>41</td>
<td>

$$\begin{array}{ccccc} Pb^{2+} & + & CrO_4^{2-} & \rightarrow & PbCrO_4 \\ 1mol & & & & 1mol \end{array}$$

$$\begin{array}{ccccccc} PbCrO_4 & + & 2Cl^- & \rightarrow & PbCl_2 & + & CrO_4^{2-} \\ 1mol & & & & & & 1mol \end{array}$$

$$\begin{array}{ccccccccccc} 2CrO_4^{2-} & + & 6I^- & + & 16H^+ & \rightarrow & 2Cr^{3+} & + & 3I_2 & + & 8H_2O \\ 2mol & & & & & & & & 3mol & & \\ 1mol & & & & & & & & 1.5mol & & \end{array}$$

</td>
</tr>
</table>

2023 Adv Higher Chemistry Marking Scheme

<table>
<tr><th>Long Qu</th><th>Answer</th><th>Reasoning</th></tr>
<tr><td>1a(i)</td><td>Answer to include:</td><td>
<table>
<tr><td>1st mark:</td><td>(Excited) electrons fall to a lower energy level</td></tr>
<tr><td>2nd mark:</td><td>Difference in energy levels corresponds to $\left\{\begin{matrix}\textit{red light}\\ \textit{light}\\ \textit{energy}\end{matrix}\right\}$ emitted.</td></tr>
</table>
</td></tr>
<tr><td>1a(ii)</td><td>
<table>
<tr><td></td><td></td><td></td><td>m_s</td></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
</table>
</td><td>
Li has electronic configuration of $1s^2\ 2s^1$. Li^+ has electronic configuration of $1s^2$
<table>
<tr><td>n</td><td>1s subshell is in 1st shell and has a value for Principal quantum number (n) of n=1</td></tr>
<tr><td>l</td><td>s subshells have an angular momentum quantum number (l) of l =0</td></tr>
<tr><td>m_l</td><td>s subshells have a magnetic quantum number (m_l) of –l to +l ∴ 0</td></tr>
<tr><td>m_s</td><td>All electrons either have a spin magnetic quantum number of either $+\frac{1}{2}$ or $-\frac{1}{2}$</td></tr>
</table>
</td></tr>
<tr><td>1a(iii)A</td><td>+7 or VII</td><td>Oxidation state of O = -2 ∴ 4xO in ClO_4^- combine to equal -8. Perchlorate ClO_4^- has charge of -1 over whole ion ∴ the oxidation state of Cl must be +7</td></tr>
<tr><td>1a(iii)B</td><td>9</td><td>
<table>
<tr><th>Bond</th><th>Number of bonds</th><th>Number of sigma</th><th>Number of Pi bonds</th></tr>
<tr><td>N – H</td><td>3</td><td>3 x 1 = 3</td><td>0</td></tr>
<tr><td>N – C</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>C = N</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>C – N</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>N – N</td><td>2</td><td>2 x 1 =2</td><td>0</td></tr>
<tr><td>N = N</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td></td><td>Total</td><td>9</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>1b(i)A</td><td>-1648</td><td>
$$\begin{aligned}\Delta H^o &= \Sigma\Delta H_f^o{}_{(products)} - \Sigma\Delta H_f^o{}_{(reactants)}\\ &= (2x\text{-}824) - (4x0) + (3x0)\\ &= -1648 - 0\\ &= -1648\ kJ\ mol^{-1}\end{aligned}$$
</td></tr>
<tr><td>1b(i)B</td><td>-549.4</td><td>
$$\begin{aligned}\Delta S^o &= \Sigma S^o{}_{(products)} - \Sigma S^o{}_{(reactants)}\\ &= (2x87.4) - (4x27.3) + (3\ x205)\\ &= 174.8 - (109.2 + 615)\\ &= 174.8 - 724.2\\ &= -549.4\ J\ K^{-1}\ mol^{-1}\end{aligned}$$
</td></tr>
<tr><td>1b(i)C</td><td>3000</td><td>
$$\Delta G^o = \Delta H^o - T\Delta S^o = 0 \quad \therefore\ T = \frac{\Delta H^o}{\Delta S^o} = \frac{-1648\ x\ 1000\ J\ mol^{-1}}{-549.4\ J\ K^{-1}\ mol^{-1}} = 3000K$$
</td></tr>
<tr><td>1b(ii)</td><td>2694g</td><td>
gfm $NaClO_3$ = (1x23)+(1x35.5)+(3x16) = 23+35.5+48 = 106.5g

1 person in 1 minute uses 0.380litres oxygen
5 persons in 1 minute uses 0.380litres oxygen x 5
= 1.9litres oxygen

5 persons in 1 hour uses 1.9litres oxygen x 60
= 114litres oxygen

5 persons in 8 hours uses 114litres oxygen x 8
= 912litres oxygen

36litres oxygen produced from 1mol $NaClO_3$
912litres oxygen produced from 1mol $NaClO_3$ x $^{912}/_{36}$
= 25.3mol $NaClO_3$

mass = no. of mol x gfm = 25.3 x 106.5 = 2694g
</td></tr>
<tr><td>2a(i)</td><td>1st Order</td><td>
<table>
<tr><th>Experiments</th><th>$[HgCl_2]$</th><th>$[C_2O_4^{2-}]$</th><th>Effect of Rate</th><th>Order</th></tr>
<tr><td>3+2</td><td>x2</td><td>same</td><td>x2</td><td>$[HgCl_2]^1$</td></tr>
</table>
</td></tr>
<tr><td>2a(ii)</td><td>2nd Order</td><td>
<table>
<tr><th>Experiments</th><th>$[HgCl_2]$</th><th>$[C_2O_4^{2-}]$</th><th>Effect of Rate</th><th>Order</th></tr>
<tr><td>1+2</td><td>same</td><td>x2</td><td>x4</td><td>$[C_2O_4^{2-}]^2$</td></tr>
</table>
</td></tr>
</table>

2b	$rate = k[HgCl_2][C_2O_4^{2-}]^2$	$rate = k \times [HgCl_2]^1 \times [C_2O_4^{2-}]^2 = k[HgCl_2][C_2O_4^{2-}]^2$
2c(i)	$2.56\times10^{-4}\ l^2\ mol^{-2}\ s^{-1}$ Or $0.000256\ l^2\ mol^{-2}\ s^{-1}$	Using Experiment 1 (although experiments 2+3 can also be used) $k = \frac{rate}{[HgCl_2][C_2O_4^{2-}]^2} = \frac{0.860\times10^{-6}\ mol\ l^{-1}\ s^{-1}}{0.0840\ mol\ l^{-1} \times (0.200)^2\ mol^2\ l^{-2}} = 2.56\times10^{-4}\ l^2\ mol^{-2}\ s^{-1}$
2c(ii)	0.508	For experiment 4: $Rate = k \times [HgCl_2] \times [C_2O_4^{2-}]^2$ $2.11\times10^{-6} = 2.56\times10^{-4} \times 0.0320 \times [C_2O_4^{2-}]^2$ $[C_2O_4^{2-}]^2 = \frac{2.11\times10^{-6}}{2.56\times10^{-4} \times 0.0320} = 0.258\ mol^2\ l^{-2}$ $[C_2O_4^{2-}] = \sqrt{0.258}\ mol\ l^{-1} = 0.508\ mol\ l^{-1}$
3a(i)	Add more/excess calcium choride solution (to see if further precipitation occurs)	When precipitation appears to be complete, the mixture is allowed to settle and more reactant is added to see if there is any further precipitation/cloudiness showing the reaction is incomplete and further reactant is added. If there is no more precipitation/cloudiness then the precipitate can be removed by vacuum filtration.
3a(ii)	The precipitate should be dried/heated in an oven and weighed until constant mass	When precipitate is removed from the filtrate by vacuum filtration, some of the water remains in the precipitate residue. Heating the precipitate in an oven will drive off water. When the precipitate is removed from the oven it is cooled in a desiccator and the mass measured in a balance. Heating in oven, cooling in a desiccator and weight on balance is repeated until constant mass is achieved.
3b	0.59	**gfm** $Ca(COO)_2 = (1\times40.1)+(2\times12)+(4\times16) = 40.1+24+64 = 128.1g$ $no.\ of\ mol = \frac{\mathbf{mass}}{\mathbf{gfm}} = \frac{0.075}{128.1} = 5.85\times10^{-4}mol$ $(COOH)_2 + CaCl_2 \longrightarrow Ca(COO)_2 + 2HCl$ 1mol → 1mol 5.85×10^{-4}mol → 5.85×10^{-4}mol gfm $(COOH)_2 = (2\times12)+(4\times16)+(2\times1) = 24+64+2 = 90g$ **mass** = **no**. of mol x **gfm** = $5.85\times10^{-4} \times 90 = 0.0527g$ $\%\ mass = \frac{\mathbf{mass\ of\ oxalic\ acid}}{\mathbf{mass\ of\ leaves}} \times100 = \frac{0.0527}{8.975}\times100 = 0.59\%$
3c	One answer from:	Not all oxalic acid extracted out Not soaked in water for long enough Not all precipitated out/not gone to completion Not enough $CaCl_2$ added Transfer loss Natural variation in samples
4	Open Question to include:	**3 mark answer**: Demonstrates a **good understanding** of the chemistry involved. A good comprehension of the chemistry has provided in a logically correct, including a statement of the principles involved and the application of these to respond to the problem. **2 mark answer**: Demonstrates a **reasonable understanding** of the chemistry involved, making some statement(s) which are relevant to the situation, showing that the problem is understood. **1 mark answer**: Demonstrates a **limited understanding** of the chemistry involved. The candidate has made some statement(s) which are relevant to the situation, showing that at least a little of the chemistry within the problem is understood.
5a	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8$	Charge in Nickel ion = +2 as H_2O is a neutral ligand so +2 charge on complex comes from Ni^{2+} ion. Ni atom: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ 4s^2$ 4s electrons are removed before 3d electrons Ni^{2+} ion: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8$

<table>
<tr>
<td>5b</td>
<td>Hexaamminenickel(II)</td>
<td>

$\underbrace{\text{Hexa}}_{\text{no. of ligands}}\underbrace{\text{ammine}}_{NH_3\text{ ligand}}\underbrace{\text{nickel}}_{\text{metal name}}\underbrace{\text{(II)}}_{\text{charge on metal ion}} = [Ni(NH_3)_6]^{2+}$

<table>
<tr><td>Neutral ligands include:</td><td>Negative Ligands include:</td><td>Central Ion:</td><td>Charge:</td></tr>
<tr>
<td>
<table>
<tr><td>Ligand</td><td>Name</td></tr>
<tr><td>H_2O</td><td>aqua</td></tr>
<tr><td>NH_3</td><td>ammine</td></tr>
<tr><td>CO</td><td>carbonyl</td></tr>
</table>
</td>
<td>
<table>
<tr><td>Ligand</td><td>Name</td></tr>
<tr><td>Chloride Cl^-</td><td>chlorido</td></tr>
<tr><td>Cyanide CN^-</td><td>cyanido</td></tr>
<tr><td>Nitrite NO_2^-</td><td>nitrito</td></tr>
</table>
</td>
<td>Positive Complex:
metals keep their name
Negative Complex:
Metals end in ATE
e.g. Cuprate, Ferrate, Cobaltate</td>
<td>Charge of central ion is converted into roman numerals and put in brackets</td>
</tr>
</table>
</td>
</tr>
<tr>
<td>5c(i)</td>
<td>Bidentate</td>
<td>A bidentate ligand has two parts of the ligand that can donate pairs of electrons to the central metal ion at the centre of the complex.</td>
</tr>
<tr>
<td>5c(ii)</td>
<td>6</td>
<td>6 different pairs of electrons across three bidentate ligands are donated to central metal ion. This gives a co-ordination number of 6.</td>
</tr>
<tr>
<td>5d(i)</td>
<td>Answer to include:</td>
<td>
<table>
<tr><td>1st mark:</td><td>Electrons move to higher energy d orbitals</td></tr>
<tr><td>2nd mark:</td><td>$\left.\begin{array}{l}\text{purple light}\\ \text{380-400nm light}\\ \text{red and blue light}\\ \text{complementary colour (to green)}\end{array}\right\}\text{absorbed}$</td></tr>
</table>
</td>
</tr>
<tr>
<td>5d(ii)</td>
<td>One answer from:</td>
<td>

$\text{Ammonia absorbs}\left\{\begin{array}{l}\text{shorter wavelength}\\ \text{higher energy}\\ \text{higher frequency}\\ \text{uv}\end{array}\right.$

</td>
</tr>
<tr>
<td>6a(i)</td>
<td>

$K=\frac{[HI]^2}{[H_2]\,[I_2]}$

</td>
<td>

For reaction: $aA + bB \rightleftharpoons cC + dD \quad K=\frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$

</td>
</tr>
<tr>
<td>6a(ii)</td>
<td>981.8</td>
<td>

I_2 at start = 0.25mol $\qquad$ I_2 at equilibrium = 0.015mol

∴ I_2 reacted = 0.25mol – 0.015mol = 0.235mol

$$\begin{array}{ccccc} H_2 & + & I_2 & \rightleftharpoons & 2HI \\ \text{1mol} & & \text{1mol} & & \text{2mol} \\ \text{0.235mol} & & \text{0.235mol} & & \text{0.470mol} \\ \text{(reacted)} & & \text{(reacted)} & & \text{(formed)} \end{array}$$

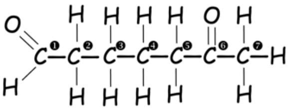
H_2 remaining at equilibrium = 0.25mol – 0.235mol = 0.015mol

$$K=\frac{[HI]^2}{[H_2]\,[I_2]}=\frac{(0.470)^2}{0.015 \times 0.015}=981.8$$

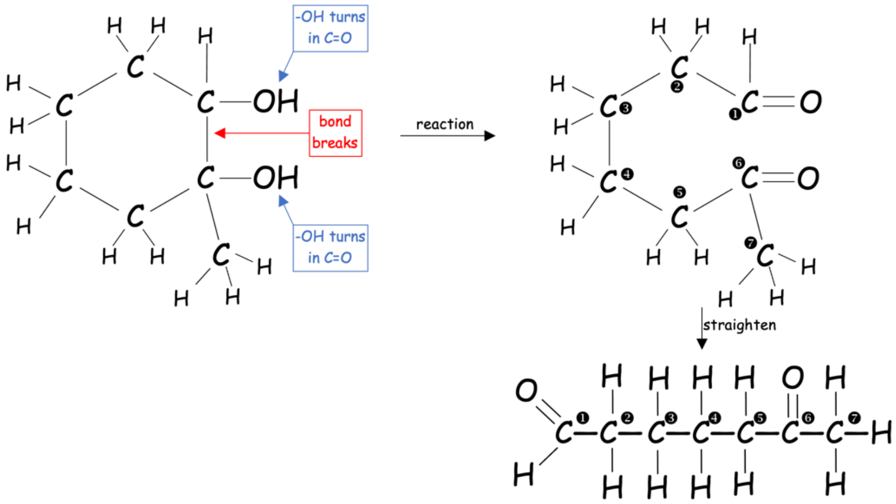
</td>
</tr>
<tr>
<td>6a(iii)</td>
<td>207.2</td>
<td>

$$\begin{aligned} E = \frac{L \times h \times c}{\lambda} &= \frac{6.02\times10^{23}\ \text{mol}^{-1} \times 6.63\times10^{-34}\ \text{J s} \times 3\times10^{8}\ \text{m s}^{-1}}{578 \times 10^{-9}\text{m}} \\ &= 207159\ \text{J mol}^{-1} \\ &= 207.2\ \text{kJ mol}^{-1} \end{aligned}$$

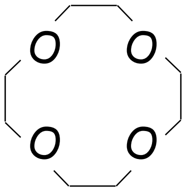
</td>
</tr>
<tr>
<td>6b(i)</td>
<td>Buchner Funnel or
Hirsch Funnel or
Sintered Glass Funnel</td>
<td>The Buchner funnel allows vacuum filtration to place which speeds up the flow of filtrate through the Buchner funnel. The reduced pressure provides a faster means to separate precipitate from filtrate</td>
</tr>
</table>

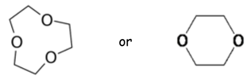
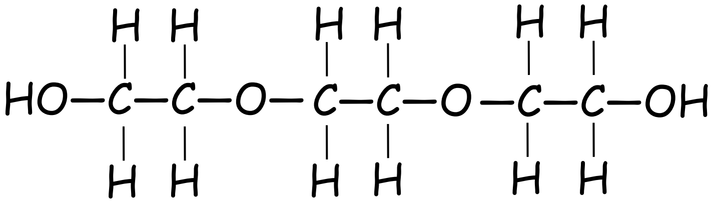
<table>
<tr><td>6b(ii)</td><td>87.4%</td><td>
gfm I_2 = (2x126.9) = 253.8g
no. of mol $I_2 = \frac{\textbf{mass}}{\textbf{gfm}} = \frac{285}{253.8}$ = 1.12mol
<table>
<tr><td>I_2</td><td>+</td><td>H_2S</td><td>$\longrightarrow$</td><td>$2HI$</td><td>+</td><td>S</td></tr>
<tr><td>1mol</td><td></td><td></td><td></td><td>2mol</td><td></td><td></td></tr>
<tr><td>1.12mol</td><td></td><td></td><td></td><td>2.25mol (theoretical)</td><td></td><td></td></tr>
</table>
gfm HI = (1x1)+(1x126.9) = 1+126.9 = 127.9g
no. of mol HI = $\frac{\textbf{mass}}{\textbf{gfm}} = \frac{251}{127.9}$ = 1.96 mol (actual)
% Yield = $\frac{\text{actual}}{\text{theoretical}}$x100 = $\frac{1.96}{2.25}$x100 = 87.4%
</td></tr>
<tr><td>6c</td><td></td><td>
Notes on example:

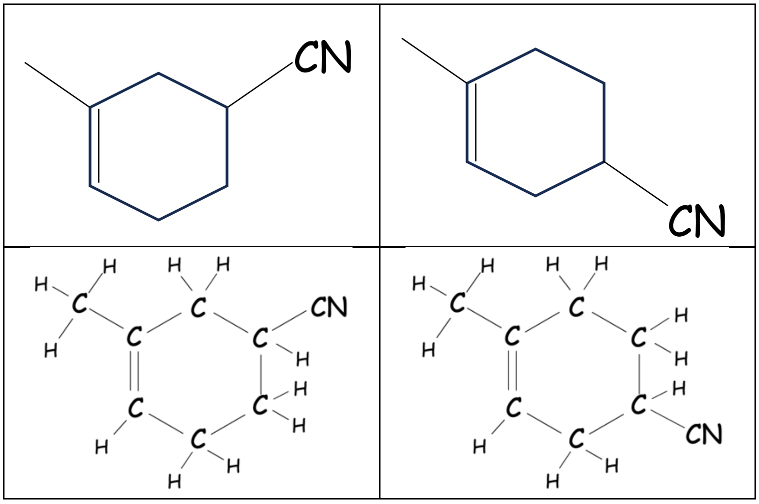
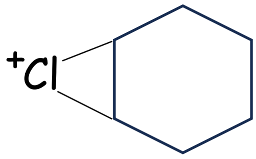
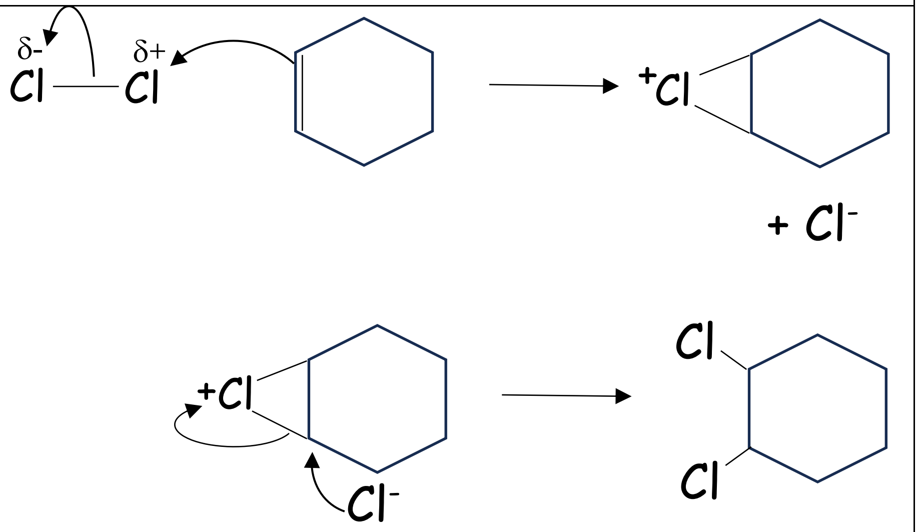
Hydroxyl -OH groups become carbonyl C=O groups
C-C single bond between carbons with hydroxyl -OH groups splits

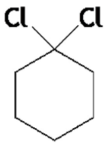


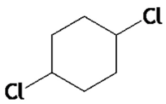
</td></tr>
<tr><td>7a</td><td>Concentration of dissolved CO_2 decreases as equilibrium moves to left.</td><td>
Increase in temperature favours the endothermic reaction
Reverse reaction is favoured as reverse reaction is endothermic
Revere reaction decreases $H_2CO_{3(aq)}$ concentration and releases $CO_{2(g)}$ into air.
</td></tr>
<tr><td>7b(i)</td><td>Carbonic acid is a weaker acid as it has higher pKa / lower K_a
or
Ethanoic acid is a stronger acid as it has lower pKa / higher K_a</td><td>
<table>
<tr><td>Weak Acid</td><td>K_a</td><td>pK_a</td></tr>
<tr><td>Carbonic acid</td><td>4.5×10^{-7}</td><td>6.35</td></tr>
<tr><td>Ethanoic acid</td><td>1.7×10^{-5}</td><td>4.76</td></tr>
<tr><td>Conclusion</td><td>Carbonic acid is a lower strength acid/weaker acid as it has a <i>smaller</i> value of K_a</td><td>Carbonic acid is a lower strength acid/weaker acid as it has a <i>higher</i> value of pK_a</td></tr>
</table>
</td></tr>
<tr><td>7b(ii)</td><td>Base
(or proton acceptor)</td><td>
<table>
<tr><td>$H_2CO_{3(aq)}$</td><td>+</td><td>$H_2O_{(l)}$</td><td>$\rightleftharpoons$</td><td>$H_3O^+_{(aq)}$</td><td>+</td><td>$HCO_3^-{}_{(aq)}$</td></tr>
<tr><td>Acid</td><td></td><td>Base</td><td></td><td>Conjugate Acid</td><td></td><td>Conjugate base</td></tr>
<tr><td>loses a proton/H^+
(proton donor)</td><td></td><td>gains a proton/H^+
(proton acceptor)</td><td></td><td>formed when base accepts a proton/H^+</td><td></td><td>formed when acid loses a proton/H^+</td></tr>
</table>
</td></tr>
<tr><td>7c(i)</td><td>6.31×10^{-9}</td><td>
$$\begin{aligned} pH &= 8.2 \\ -\log_{10}[H_3O^+] &= 8.2 \\ \log_{10}[H_3O^+] &= -8.2 \\ [H_3O^+] &= 10^{-8.2} \\ [H_3O^+] &= 6.31 \times 10^{-9}\ \text{mol l}^{-1} \end{aligned}$$
</td></tr>
</table>

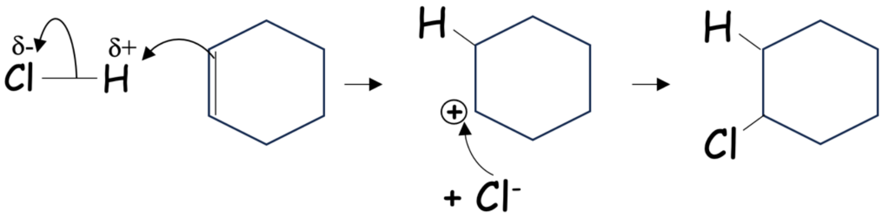
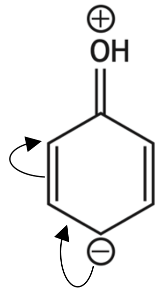
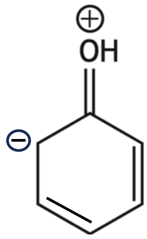
<table>
<tr><td>7c(ii)</td><td>99.7%</td><td><table><tr><td>pH = 7.9
$-\log_{10}[H_3O^+]$ = 7.9
$\log_{10}[H_3O^+]$ = -7.9
$[H_3O^+]$ = $10^{-7.9}$
$[H_3O^+]$ = 1.26×10^{-8} mol l^{-1}</td><td>% Increase = $\frac{\text{difference in value}}{\text{original value}}$ x100
% Increase = $\frac{1.26\times10^{-8} - 6.31\times10^{-9}}{\mathbf{6.31\times10^{-9}}}$ x100
% Increase = $\frac{6.29\times10^{-9}}{\mathbf{6.31\times10^{-9}}}$ x100
% Increase = 99.7%</td></tr></table></td></tr>
<tr><td>7d(i)</td><td>Answer to include:</td><td><table><tr><td>Reacting known mass of seashells with an excess volume of a hydrochloric acid of known concentration</td><td>The resulting mixture is then titrated with sodium hydroxide to work out the number of moles of hydrochloric acid in excess</td><td>From the initial number of moles of hydrochloric acid, the number of moles used in the reaction can be determined.</td><td>The initial number of moles of the calcium carbonate in seashells being analysed can then be calculated.</td></tr></table></td></tr>
<tr><td>7d(i)</td><td>Answer to include:
All 4 points = 2marks
2 or 3 points = 1 mark</td><td><table><tr><td>React calcium carbonate /shells with HCl/acid</td><td>Known quantity/moles/volume and concentration of HCl/acid</td><td>idea of excess HCl/acid</td><td>titrate with NaOH.</td></tr></table></td></tr>
<tr><td>7d(ii)</td><td>Repeat using pure calcium carbonate</td><td>In a control experiment, a known mass of pure calcium carbonate can assess the accuracy of the reaction method.</td></tr>
<tr><td>8a(i)</td><td>15-crown-5</td><td>In example given 18-crown-6:
18 refers to the number of atoms in the ring and 6 refers to number of oxygens
The question: 15 atoms in the ring and 5 oxygen atoms in ring ∴ 15-crown-5</td></tr>
<tr><td>8a(ii)</td><td>

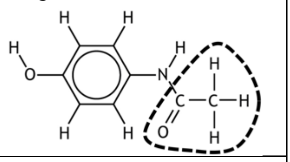
Also accepted:

</td><td><table><tr><th>Element</th><th>Member of Group 1</th><th>Number of O in ether</th><th>Name</th></tr><tr><td>Li</td><td>1st</td><td>4</td><td>12-crown-4</td></tr><tr><td>Na</td><td>2nd</td><td>5</td><td>15-crown-5</td></tr><tr><td>K</td><td>3rd</td><td>6</td><td>18-crown-6</td></tr></table></td></tr>
<tr><td>8a(iii)</td><td>Can donate lone (non-bonding) pairs of electrons</td><td>Ligands have lone pairs of electrons which for dative covalent bonds by donating pairs of electrons to the central metal ion forming dative covalent bonds.
In crown ethers, the lone pair electrons are pointing into the centre of the ring where the metal ion is located.</td></tr>
<tr><td>8b(i)</td><td>$C_6H_{14}O_4$</td><td>
$HO-CH_2-CH_2-O-CH_2-CH_2-O-CH_2-CH_2-OH$</td></tr>
<tr><td>8b(ii)</td><td>Condensation
or
nucleophilic substitution</td><td>H from one molecule and Cl from next molecule are removed as the molecules join together forming HCl</td></tr>
<tr><td>8c</td><td>2.43×10^{-3}
or
0.0024</td><td>**gfm** 18-Crown-6 = 264g
no. of mol = $\frac{\textbf{mass}}{\textbf{gfm}}$ = $\frac{0.225}{264}$ = 8.52×10^{-4}mol
As K^+ ions and 18-crown-6 are in 1:1 ratio: 8.52×10^{-4}mol K^+ ions
concentration = $\frac{\text{no. of mol}}{\text{volume}}$ = $\frac{8.52\times10^{-4}\text{ mol}}{0.350\text{ litres}}$ = 2.43×10^{-3}mol l^{-1}</td></tr>
</table>

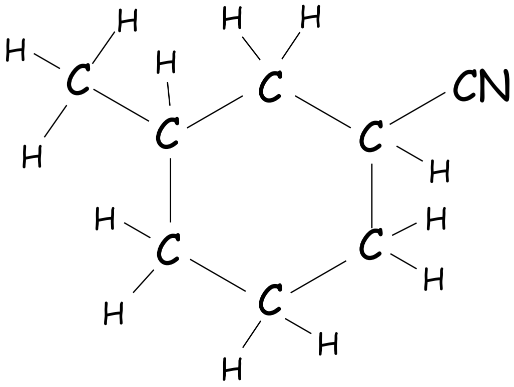
9	Open Question to include:	**3 mark answer** Demonstrates a **good understanding** of the chemistry involved. A good comprehension of the chemistry has provided in a logically correct, including a statement of the principles involved and the application of these to respond to the problem. **2 mark answer** Demonstrates a **reasonable understanding** of the chemistry involved, making some statement(s) which are relevant to the situation, showing that the problem is understood. **1 mark answer** Demonstrates a **limited understanding** of the chemistry involved. The candidate has made some statement(s) which are relevant to the situation, showing that at least a little of the chemistry within the problem is understood.
10a(i)	One answer from:	Adjacent (unhybridised) p orbitals that overlap/form a molecular orbital across a system/number of carbon atoms Electrons delocalised across a number of carbon atoms Alternating single and double bonds
10a(ii)	sp^2	C=C double bonds contain sp^2 hybridisation with a C-C sigma bond down the axis of the bond and side on overalp of unhybridised orbitals to form the pi bond.
10a(iii)	One from:	
10b(i)	Repulsion from pi electrons or double bond	The electrons Cl-Cl bond are repelled by the pi electrons in the C=C double bond and this polarises the Cl-Cl bond forming a $\delta+$ end and a $\delta-$ end
10b(ii)		
10b(iii)A	Restricted rotation/ lack of free rotation (around the single bonds) in the ring	The ring of six carbons prevents the rotation so there are two locked positions for side groups above and below the ring with no rotation. • if both side groups are above ring then this is the cis geometric isomer • if one side group is above ring and the other side group below ring then this is the trans geometric isomer. A C=C double bond also has a lack or rotation in the bond due to the Pi bond so that also has the geometric isomers

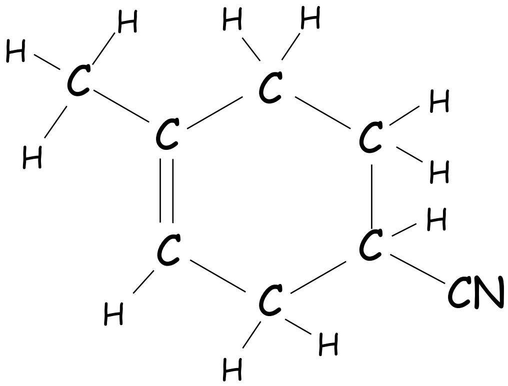
<table>
<tr><td>10b(iii)B</td><td>structure drawn of
1,1-dichlorocyclohexane


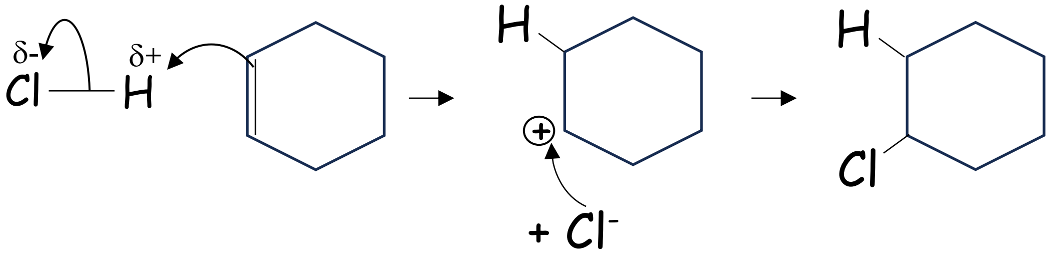
or


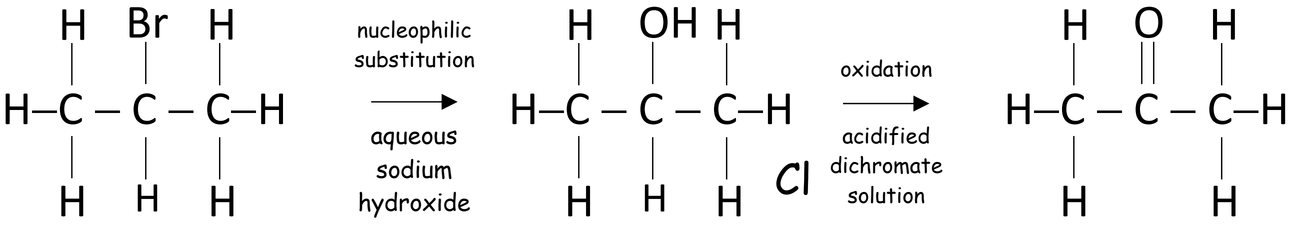
1,4-dichlorocyclohexane</td><td>An optical isomer has a chiral carbon with four different groups attached.
1,1-dichlorocyclohexane has no carbons with four different groups. C_1 has two chlorine atoms and the other carbons each have two hydrogens.
1,4-dichlorocyclohexane lacks a chiral carbons as C_1 and C_4 each have a hydrogen atom and a chlorine atom but the ring of carbons is symmetrical and are identical regardless of which way you go around the ring.</td></tr>
<tr><td>10c(i)</td><td>Diagram showing:
1 mark for curly arrows
1 mark for correct intermediate</td><td>
 </td></tr>
<tr><td>10c(ii)</td><td>1.08</td><td>e = $1.60\times10^{-19}C$ partial charge = 0.178
$Q = \text{partial charge} \times e = 0.178 \times 1.60\times10^{-19}\,C = 2.848\times10^{-20}\,C$
$Q = 2.848\times10^{-20}\,C$ $r = 0.127nm = 0.127\times10^{-9}m = 1.27\times10^{-10}m$
$\mu = Q \times r = 2.848\times10^{-20}\,C \times 1.27\times10^{-10}m = 3.62\times10^{-30}\,Cm$
$3.34\times10^{-30}\,Cm = 1\,D$
$3.62\times10^{-30}\,Cm = 1\,D \times \frac{3.62\times10^{-30}\,Cm}{3.34\times10^{-30}\,Cm}$
$= 1.08\,D$</td></tr>
<tr><td>11a(i)</td><td>NO_2^+</td><td>Nitration electrophilic substitution reactions involve concentrated nitric acid and concentrated sulphuric acid and forms the electrophile nitronium NO_2^+ ion
$\underset{\text{concentrated nitric acid}}{HNO_3} + \underset{\text{concentrated sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{nitronium ion}}{NO_2^+} + \underset{\text{hydronium ion}}{H_3O^+} + \underset{\text{hydrogensulphate ion}}{HSO_4^-}$</td></tr>
<tr><td>11a(ii)A</td><td>
 </td><td></td></tr>
<tr><td>11a(ii)B</td><td>
 </td><td></td></tr>
<tr><td>11b</td><td>Reduction</td><td>Decrease in the oxygen : hydrogen ratio
<table>
<tr><td>Formula</td><td>$C_6H_4O_3$</td><td>C_6H_7O</td></tr>
<tr><td>O : H ratio</td><td>3 : 4
1 : 1.33</td><td>1 : 7</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>11c</td><td>Ethanoic acid
or
Ethanoic anhydride
or
Ethanoyl chloride</td><td>Amines react with carboxylic acids to form alkylammonium salts and form an amide when heated.</td></tr>
<tr><td>11d</td><td>Answer to include:</td><td>2 marks for all 4 points in table. 1 mark for 2 or 3 points in table<table><tr><td>minimum/small volume (of solvent)</td><td>hot water/solvent</td><td>cool</td><td>filter</td></tr></table></td></tr>
<tr><td>11e(i)A</td><td>C=O or Carbonyl</td><td></td></tr>
<tr><td>11e(i)B</td><td>Overlap of peaks from different bonds with one example as shown:</td><td>O-H peak in same region as N-H
C-H
or
N-H peak in same region as O-H
C-H</td></tr>
<tr><td>11e(ii)A</td><td>CH_3-C=O circled:
</td><td rowspan="2"><table>
<tr><td>Chemical Shift (ppm)</td><td>2.1</td><td>6.7</td><td>7.3</td><td>9.1</td><td>9.8</td></tr>
<tr><td>Height of Curve (mm)</td><td>50</td><td>33</td><td>33</td><td>17</td><td>17</td></tr>
<tr><td>No of Hydrogens in Group</td><td>3</td><td>2</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td>Multiplet</td><td>singlet</td><td>doublet</td><td>doublet</td><td>singlet</td><td>singlet</td></tr>
<tr><td>No of Hydrogen next door</td><td>0</td><td>2</td><td></td><td>0</td><td>0</td></tr>
<tr><td>Group</td><td>$CH_3C=O$</td><td>ArH?</td><td></td><td>-HN-C=O</td><td>Ar-OH</td></tr>
</table></td></tr>
<tr><td>11e(ii)B</td><td>Doublet
Doublet</td></tr>
<tr><td>11e(iii)A</td><td>Sample is pure with no extra peaks or only 5 (hydrogen) peaks</td><td>The same number of peaks with the same chemical shift indicated the sample is pure as contaminants would add other peaks to the NMR spectrum as they would containing other chemical groups.</td></tr>
<tr><td>11e(iii)B</td><td>Mixed melting point or TLC or Chromatography</td><td>The melting point of the recrystalised paracetamol is measured using melting point apparatus. Pure paracetamol is added to see if the melting point is the same. If the melting point alters then the sample is not pure.</td></tr>
</table>

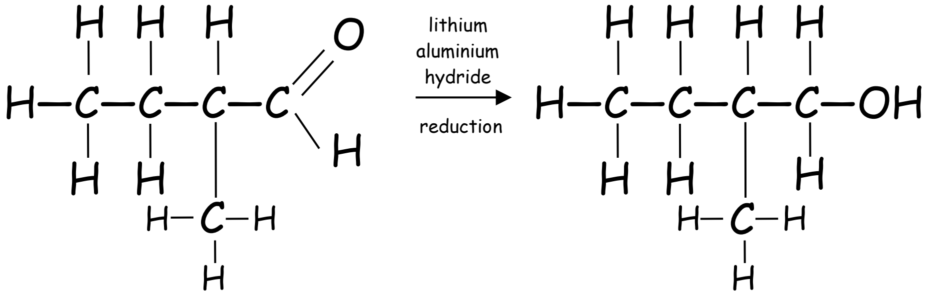


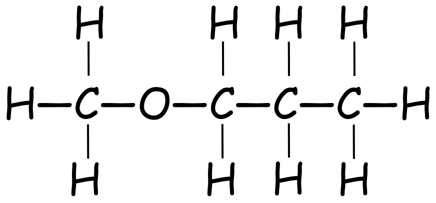


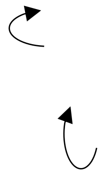

δ-
δ+
Cl
H
H
+
+ Cl-
H
Cl

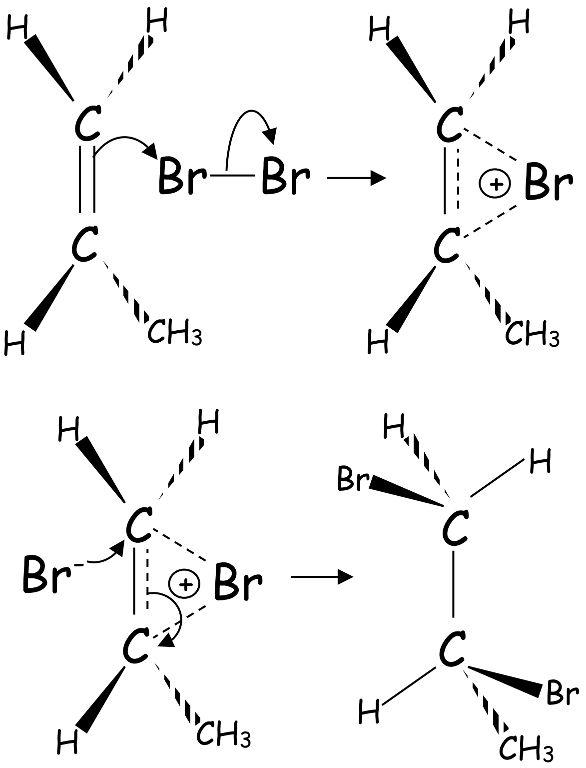

nucleophilic substitution
aqueous sodium hydroxide
Cl
oxidation
acidified dichromate solution

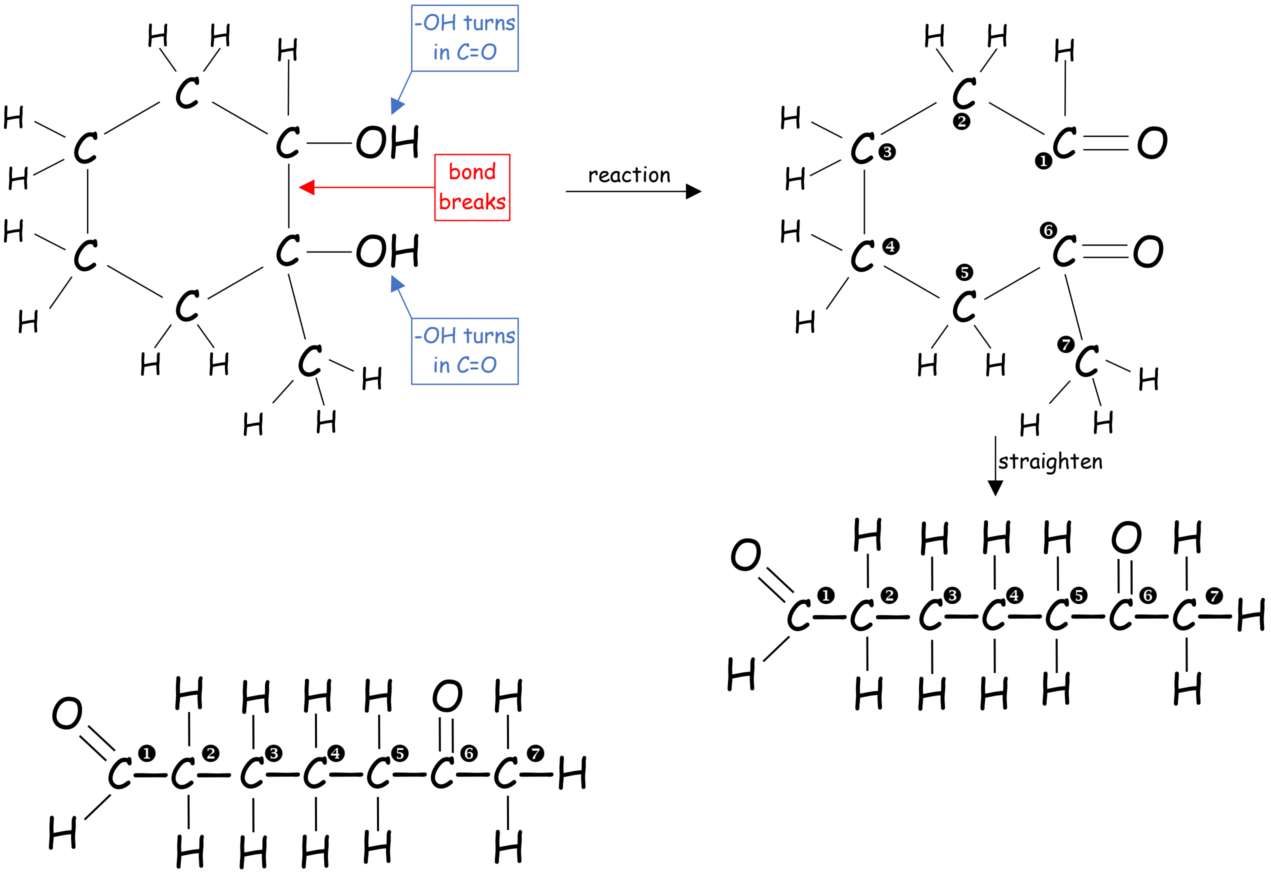
secondary bromoalkane
secondary alcohol
Ketone


lithium aluminium hydride
reduction








-OH turns in C=O
bond breaks
-OH turns in C=O
reaction
straighten