JABchem

Past Papers
Advanced Higher
Chemistry

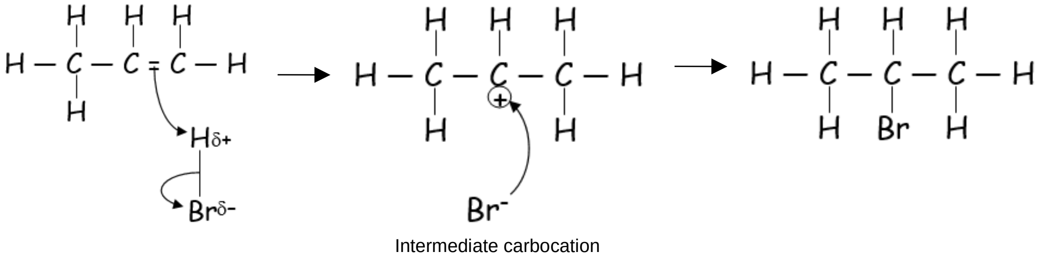
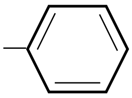
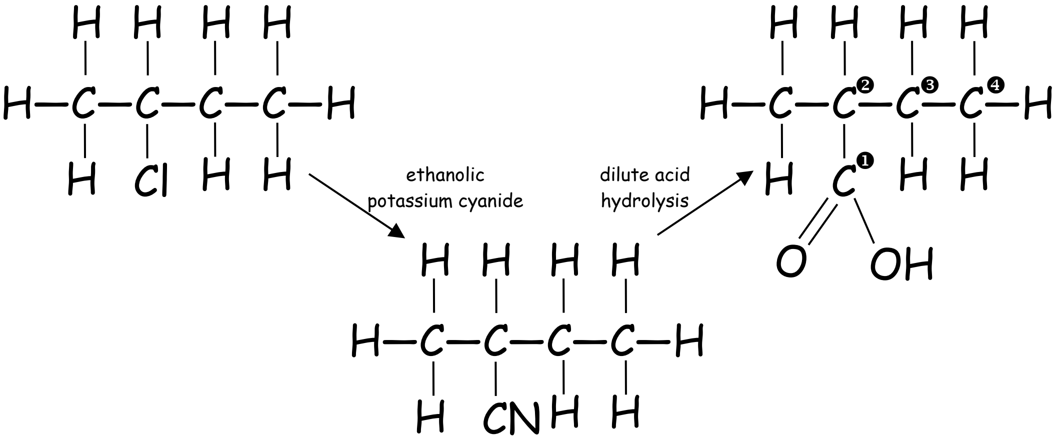
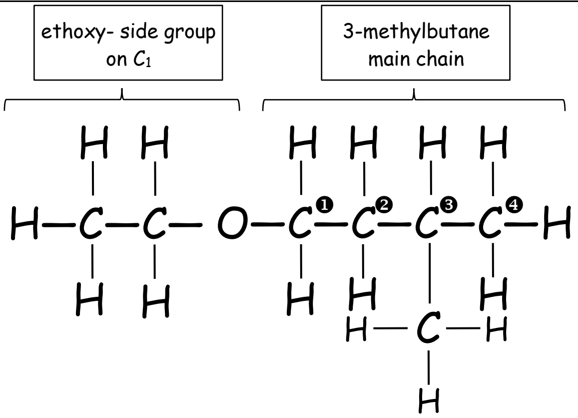
2022
Marking Scheme

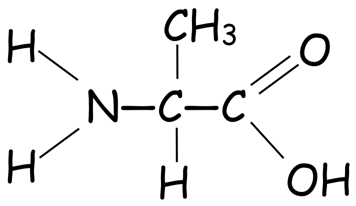
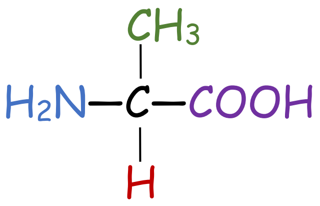
Grade Awarded	Mark Required		% candidates achieving grade
	(/120)	%	
A	77+	64.1%	32.6%
B	62+	51.7%	28.7%
C	48+	40%	20.7%
D	33+	27.5%	12.7%
No award	<33	<27.5%	5.3%

Section:	Multiple Choice	Extended Answer	Project
Average Mark:	15.7 /25	50.4 /95	No Project in 2022

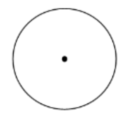
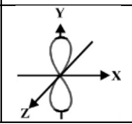
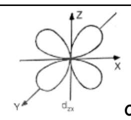
2022 Adv Higher Chemistry Marking Scheme

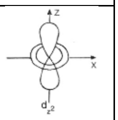
<table>
<tr><th>MC Qu</th><th>Answer</th><th>% Pupils Correct</th><th>Reasoning</th></tr>
<tr><td>1</td><td>B</td><td>66</td><td>☒A Each element does have a characteristic spectrum
☑B Heat energy is used to promote electrons in emission spectroscopy
☒C Lines are formed by electrons releasing energy as they drop down energy levels
☒D More electrons dropping down levels leads to more intense lines formed</td></tr>
<tr><td>2</td><td>D</td><td>60</td><td>Cr atom electronic configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$
Cr^+ ion electronic configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$</td></tr>
<tr><td>3</td><td>D</td><td>61</td><td>Octahedral complex ion means M^{2+} ion makes 6 dative covalent bonds with ligands.
- L^- is a bidentate ligand making 2 dative covalent bonds with M^{2+}
- M^{2+} pairs up with 3 L^- bidentate ligands
- Formula of complex ion = $[ML_3]^-$</td></tr>
<tr><td>4</td><td>A</td><td>83</td><td>☑A homogeneous catalysts are in the same state as the reactants
☒B Adsorption of reactive molecules must take place in heterogeneous catalysis
☒C A catalyst will reduce the activation energy for a reaction pathway
☒D catalysts are often transition metals due to unpaired d electrons in mechanism</td></tr>
<tr><td>5</td><td>D</td><td>41</td><td>☒A $\mathbf{Cl}$ is reduced to Cl^- and $\mathbf{I^-}$ is oxidised to I_2 but are different substance
☒B $\mathbf{IO_3}$ is reduced to I_2 and $\mathbf{I^-}$ is oxidised to I_2 but are different substances
☒C $\mathbf{Cl_2}$ is reduced to Cl^- and $\mathbf{I_2}$ is oxidised to IO_3^- but are different substances
☑D $\mathbf{Cl_2}$ is reduced to Cl^- and at the same time $\mathbf{Cl_2}$ is oxidised to ClO^-
<table>
<tr><td>Reaction</td><td>Reduction reaction</td><td>Oxidation Reaction</td></tr>
<tr><td>Equation</td><td>$\mathbf{Cl_2} + 2e^- \rightarrow 2Cl^-$</td><td>$\mathbf{Cl_2} + 2H_2O \rightarrow 2ClO^- + 4H^+ + 2e^-$</td></tr>
<tr><td>Oxidation State</td><td>0 -1</td><td>0 +1</td></tr>
</table></td></tr>
<tr><td>6</td><td>C</td><td>45</td><td>☒A pH = 7.00 is true at 25°C (298K)
☒B The ionic product $K_w=[H_3O^+][OH^-] = 1.01\times10^{-14}$ is only true at 25°C (298K)
☑C $[H_3O^+] = [OH^-]$ is true for any neutral solution at any temperature
☒D $[H_3O^+] = 1.00\times10^{-7}$ at 25°C (298K)</td></tr>
<tr><td>7</td><td>A</td><td>54</td><td>☑A $[SO_3]$ will increase with an increase in pressure but value of K is unchanged
☒B Changes to pressure do not change the value of the equilibrium constant K
☒C Increase in pressure will favour pressure-reducing forward reaction ∴ ↑ $[SO_3]$
☒D Increase in pressure will favour pressure-reducing forward reaction ∴ ↑ $[SO_3]$</td></tr>
<tr><td>8</td><td>D</td><td>62</td><td>enthalpy of formation is the energy change for the formation of 1mol of a substance from its elements in their natural state.
☒A Reactants are ions and not elements in their natural state
☒B Reactants are ions and not elements in their natural state
☒C $Cl_{(g)}$ is not the natural state of chlorine $Cl_{2(g)}$
☑D Reactants are elements in their natural state and 1 mole of product is formed</td></tr>
<tr><td>9</td><td>B</td><td>83</td><td>Rate = $k[A]^2[B]$
∴ $[A]^2$ means A is 2nd order (caused by having two particles of A in rate determining step)
∴ $[B]^1$ means B is 1st order (caused by having one particles of B in rate determining step)
☒A Doubling [A] leads to a quadrupling of reaction rate as A is 2nd order
☑B Doubling [B] leads to a doubling of reaction rate as B is 1st order
☒C Doubling [B] leads to a doubling of reaction rate as B is 1st order
☒D Doubling [A] and [B] would lead to a combined quadrupling of reaction rate.</td></tr>
<tr><td>10</td><td>D</td><td>77</td><td>☒A The order of each reactant is not decided by stoichiometric coefficients
☒B The order of a reaction is decided by the slow rate determining step
☒C The speed of reaction is determined by the slowest step – rate determining step
☑D The individual orders are determined by experimentally altering concentrations and looking to see the effect on the reaction rate.</td></tr>
</table>

<table>
<tr><td>11</td><td>C</td><td>65</td><td>☒A there are no changes of state in this graph (indicated by vertical sections)
☒B there are no changes of state in this graph (indicated by vertical sections)
☑C Evaporation (2nd vertical section) gives a bigger increase in entropy than melting
☒D Evaporation (2nd vertical section) gives a bigger increase in entropy than melting</td></tr>
<tr><td>12</td><td>C</td><td>54</td><td>☒A diagram shows sp^3 hybridisation as one 2s and three 2p orbitals have hybridised
☒B diagram shows sp^2 hybridisation as one 2s and two 2p orbitals have hybridised
☑C diagram shows sp hybridisation as one 2s and one 2p orbitals have hybridised
☒D none of the three 2p orbitals have hybridised in this diagram</td></tr>
<tr><td>13</td><td>B</td><td>92</td><td>
<table>
<tr><td>Answer</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>Formula</td><td>C_2H_4</td><td>H_2O</td><td>O_2</td><td>N_2</td></tr>
<tr><td>Bonds</td><td>4x C–H 1x C=C</td><td>2x O-H</td><td>1x O=O</td><td>1x $N\equiv N$</td></tr>
<tr><td>Sigma Bonds</td><td>5</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td>Pi Bonds</td><td>1</td><td>0</td><td>1</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>14</td><td>A</td><td>54</td><td> </td></tr>
<tr><td>15</td><td>D</td><td>50</td><td>A phenyl group is a benzene ring attached as a side-group.
Benzene has a formula of C_6H_6 side group has a formula of $-C_6H_5$ </td></tr>
<tr><td>16</td><td>C</td><td>74</td><td> </td></tr>
<tr><td>17</td><td>B</td><td>57</td><td> </td></tr>
<tr><td>18</td><td>D</td><td>66</td><td>☒A H atom available on right side to rearrange C=O group to form -OH group
☒B H atom available on right side to rearrange C=O group to form -OH group
☒C H atom available on left side to rearrange C=O group to form -OH group
☑D no H atoms available on either side to rearrange C=O group to form -OH group</td></tr>
</table>

<table>
<tr><td>19</td><td>B</td><td>71</td><td>
A chiral carbon is a carbon with four different groups attached. This leads to non-superimposable mirror images in three dimensions

$H_2N-\overset{CH_3}{\underset{H}{C}}-COOH$</td></tr>
<tr><td>20</td><td>C</td><td>78</td><td>☒A Formula C_4H_4
☒B Formula C_4H_6
☑C Formula C_4H_8 fits empirical formula CH_2
☒D Formula C_4H_{10}
<table>
<tr><td>Element</td><td>C</td><td>H</td></tr>
<tr><td>Mass or %</td><td>0.12g</td><td>0.02g</td></tr>
<tr><td>No. of moles
(divide % by gfm)</td><td>$\frac{0.12}{12}$
= 0.01</td><td>$\frac{0.02}{1}$
= 0.02</td></tr>
<tr><td>Mole ratio
(divide through by smallest value)</td><td>$\frac{0.01}{0.01}$
= 1</td><td>$\frac{0.02}{0.01}$
= 2</td></tr>
<tr><td>Empirical Formula</td><td colspan="2">CH_2</td></tr>
</table></td></tr>
<tr><td>21</td><td>B</td><td>70</td><td>☒A $C_3H_8O_2$ has gfm= (3x12)+(8x1)+(2x16) = 36+8+32 = 76
☑B $C_3H_6O_2$ has gfm= (3x12)+(6x1)+(2x16) = 36+6+32 = 74
☒C C_3H_8O has gfm= (3x12)+(8x1)+(1x16) = 36+8+16 = 72
☒D C_3H_8O has gfm= (3x12)+(8x1)+(1x16) = 36+8+16 = 72</td></tr>
<tr><td>22</td><td>A</td><td>66</td><td>$\text{no. of mol} = \frac{\text{mass}}{\text{gfm}} = \frac{6.7}{134} = 0.05\text{mol}$
sodium carbonate + malic acid → sodium malate + water + carbon dioxide
$Na_2CO_3 + C_4H_6O_5 \rightarrow Na_2C_4H_4O_5 + H_2O + CO_2$
1mol 1mol
0.05mol 0.05mol</td></tr>
<tr><td>23</td><td>B</td><td>60</td><td>gfm $CaCl_2•2H_2O$ = (1x40.1)+(2x35.5)+(4x1)+(2x16) = 40.1+71+4+32 = 147.1g
gfm $CaCl_2$ = (1x40.1)+(2x35.5) = 40.1+71 = 111.1g
$CaCl_2•2H_2O \rightarrow CaCl_2 + 2H_2O$
1mol 1mol
147.1g 111.1g
2.52g $111.1g \times {}^{2.52}/_{147.1}$
= 1.90g</td></tr>
<tr><td>24</td><td>A</td><td>39</td><td>☑A Distillation will identify the boiling point of compound while purifying compound
☒B Recrystallisation will purify a compound but not help identify the compound
☒C Solvent Extraction will purify a compound but not help identify the compound
☒D Melting Point Determination will identify a compound but not purify compound</td></tr>
<tr><td>25</td><td>B</td><td>38</td><td>☒A Impurities could move same distance as spot
☑B There is no reactant left (R) and only the product spot (S) is present
☒C More than one chemical could be present in the spot at (S)
☒D Some reactions at equilibrium neve reach completion</td></tr>
</table>

2022 Adv Higher Chemistry Marking Scheme

<table>
<tr><th>Long Qu</th><th>Answer</th><th>Reasoning</th></tr>
<tr><td>1a(i)</td><td>∞
figure of 8 shape</td><td>
<table>
<tr><th>Subshell Type</th><th>s</th><th>p</th><th>d</th></tr>
<tr><td>Angular Momentum Quantum number (l)</td><td>l =0</td><td>l =1</td><td>l=2</td></tr>
<tr><td>Shape(s)</td><td></td><td>
</td><td>

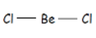
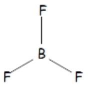
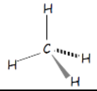
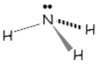
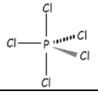
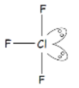
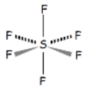
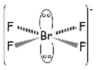
or

</td></tr>
</table>
</td></tr>
<tr><td>1a(ii)</td><td>
<table>
<tr><td>n</td><td>2</td></tr>
<tr><td>l</td><td>1</td></tr>
<tr><td>m_l</td><td>-1 or 0 or +1</td></tr>
<tr><td>m_s</td><td>$+\frac{1}{2}$ or $-\frac{1}{2}$</td></tr>
</table>
</td><td>
<table>
<tr><td>n</td><td>2p subshell is in 2nd shell and has a value for Principal quantum number (n) of n=2</td></tr>
<tr><td>l</td><td>p subshells have an angular momentum quantum number (l) of l =1</td></tr>
<tr><td>m_l</td><td>p subshells have a magnetic quantum number (m_l) of -l to +l ∴ -1, 0, +1</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>1b</td><td>Removing electron from oxygen creates a half-filled 2p orbital requires less energy as a half-filled p subshell is more stable.

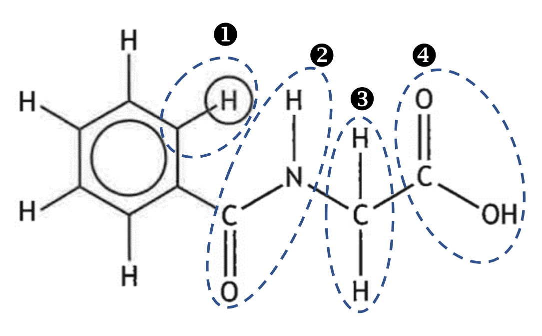
Or

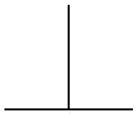
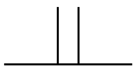
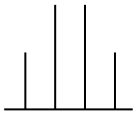
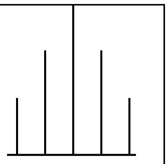
Removing an electron from nitrogen breaks a more stable half-filled 2p orbital which required more energy to break</td><td>
<table>
<tr><th>Element</th><th>Nitrogen N</th><th>Oxygen O</th></tr>
<tr><td>Electronic configuration before electron removal</td><td>$1s^2\ 2s^2\ 2p^3$ 2p [↿][↿][↿]</td><td>$1s^2\ 2s^2\ 2p^4$ 2p [↿⇂][↿][↿]</td></tr>
<tr><td>Electronic configuration after electron removal</td><td>$1s^2\ 2s^2\ 2p^2$ 2p [↿][↿][ ]</td><td>$1s^2\ 2s^2\ 2p^3$ 2p [↿][↿][↿]</td></tr>
<tr><td>Reasoning</td><td>Nitrogen atom has a half-filled 2p orbital and this is more stable electron configuration than the N^+ ion with 2 electrons in the 2p orbital. More energy required to remove an electron from a half-filled subshell.</td><td>Oxygen atom has 4 electrons in 2p orbitals and losing an electron to become O^+ ion creates the more stable half-filled subshell. Less energy is required to create a half-filled subshell by removing an electron.</td></tr>
</table>
</td></tr>
<tr><td>1c</td><td>1.05×10^{-16}</td><td>
$E = R \times Z^2 \times (1 - \frac{1}{n^2})$
$= 2.18\times10^{-18} \times (8)^2 \times (1 - \frac{1}{2^2})$
$= 2.18\times10^{-18} \times 64 \times (1 - 0.25)$
$= 2.18\times10^{-18} \times 64 \times (0.75)$
$= 1.0464 \times10^{-16}$ J
</td></tr>
<tr><td>2a</td><td>Reaction not feasible at 298K as ΔG=+86.6kJ mol^{-1}</td><td>
$\Delta H^o = \Sigma\Delta H_f^o(\text{products}) - \Sigma\Delta H_f^o(\text{reactants})$
$= (1\text{x}90.3) - (\frac{1}{2}\text{x}0) + (\frac{1}{2}\text{x}0)$
$= 90.3 - 0$
$= 90.3\ \text{kJ mol}^{-1}$

$\Delta S^o = \Sigma S^o(\text{products}) - \Sigma S^o(\text{reactants})$
$= (1\text{x}211) - (\frac{1}{2}\text{x}192) + (\frac{1}{2}\text{x}205)$
$= 211 - (96 + 102.5)$
$= 211 - 198.5$
$= 12.5\ \text{J K}^{-1}\ \text{mol}^{-1}$

$\Delta G^o = \Delta H^o - T\Delta S^o = 90.3 - (298\text{x}\frac{12.5}{1000}) = 90.3 - (3.725) = +86.6\ \text{kJ mol}^{-1}$
</td></tr>
<tr><td>2b</td><td>600mg
or
0.6g</td><td>5 litres per minute = 300 litres per hour
2ppm = 2mg per litre
1litre = 2mg
300 litres = 2mg x $^{300}/_{1}$
= 600 mg</td></tr>
<tr><td>2c</td><td>+2
+4
+3</td><td>
<table>
<tr><td>NO</td><td>total oxidation state from O = 1 x -2 = -2</td><td>∴ Oxidation state of N = +2</td></tr>
<tr><td>NO_2</td><td>total oxidation state from O = 2x -2 = -4</td><td>∴ Oxidation state of N = +4</td></tr>
<tr><td>N_2O_3</td><td>total oxidation state from O = 3x -2 = -6</td><td>∴ Oxidation State of N = $^{+6}/_{2}$ = +3</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>2d(i)A</td><td>Rate = k $[NO]^2 [H_2]$</td><td>
<table>
<tr><th>no. of mol in slow step</th><th>Order of Reactant</th><th>Effect on Reactant</th><th>Rate Equation</th></tr>
<tr><td>2mol NO</td><td>2nd order</td><td>$[NO]^2$</td><td>Rate = k $[NO]^2 [H_2]$</td></tr>
<tr><td>1mol H_2</td><td>1st order</td><td>$[H_2]$</td><td></td></tr>
</table>
</td></tr>
<tr><td>2d(i)B</td><td>9.94×10^{-3}
or
0.0099</td><td>$[NO]^2 = \frac{Rate}{K[H_2]} = \frac{0.0040}{2.7 \times 10^3 \times 0.015} = 9.87 \times 10^{-5}$
$[NO] = 9.94 \times 10^{-3}$ mol l^{-1}</td></tr>
<tr><td>2d(ii)</td><td>Equation showing:</td><td>$2NO + 2H_2 \longrightarrow N_2 + 2H_2O$</td></tr>
<tr><td>3a</td><td>acid partially dissociates into ions</td><td>Strong acids are acids which fully dissociates into ions
Weak acids are acids with partially dissociate into ions.</td></tr>
<tr><td>3b(i)</td><td>1.298</td><td>$pH = \frac{1}{2}pK_a - \frac{1}{2}\log_{10}c$
$pH = \frac{1}{2}(3.17) - \frac{1}{2}\log_{10}(3.75)$
$pH = 1.585 - \frac{1}{2}(0.574)$
$pH = 1.585 - 0.287$
$pH = 1.298$</td></tr>
<tr><td>3b(ii)</td><td>7.5%</td><td>gfm HF = (1x1)+(1x19) = 1+19 = 20g
3.75mol of HF in 1litre of solution ∴ mass = no. of mol x gfm = 3.75 x 20 = 75g
1 litre of HF solution would have approx. mass of 1000g $\frac{75g}{1000g} \times 100 = 7.5\%$</td></tr>
<tr><td>3b(iii)</td><td>tetrahedral</td><td>
<table>
<tr><td>2
electron pairs</td><td>3
electron pairs</td><td>4
electron pairs</td><td>4
electron pairs</td><td>4
electron pairs</td><td>5
electron pairs</td><td>5
electron pairs</td><td>6
electron pairs</td><td>6
electron pairs</td></tr>
<tr><td>2 bonding
+ 0 lone pairs</td><td>3 bonding
+ 0 lone pairs</td><td>4 bonding
+ 0 lone pairs</td><td>3 bonding
+ 1 lone pairs</td><td>2 bonding
+ 2 lone pairs</td><td>5 bonding
+ 0 lone pairs</td><td>3 bonding
+ 2 lone pairs</td><td>6 bonding
+ 0 lone pairs</td><td>4 bonding
+ 2 lone pairs</td></tr>
<tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr>
<tr><td>Linear</td><td>Trigonal Planar</td><td>Tetrahedral</td><td>Trigonal Pyramidal</td><td>Angular</td><td>Trigonal Bipyramidal</td><td>T-Shaped</td><td>Octahedral</td><td>Square Planar</td></tr>
</table>
Electron pairs $= \frac{\text{No of outer electrons on central atom} + \text{no. of bonds} - \text{charge}}{2}$
$= \frac{4 + 4 - 0}{2}$
$= \frac{8}{2}$
= 4 pairs of electrons (4 bonding pairs)
</td></tr>
<tr><td>4a(i)A</td><td>Heating under reflux</td><td rowspan="2">Heating under reflux allows heating of a chemical reaction mixture over an extended period of time without volatile substances escaping
• a round-bottomed flask is used containing anti-bumping granules to reduce bumping of reactants in the flask
• flask is fitted with a condenser to allow condensation of reaction mixture vapour and prevents escape of volatile chemicals
• flask is heated using an appropriate heat source e.g. heating mantle it there are flammable reactant/products involved.</td></tr>
<tr><td>4a(i)B</td><td>Anti-bumping granules</td></tr>
<tr><td>4a(ii)</td><td>Answer to include:</td><td>
few ions mainly molecules
H^+ ions and negative in of salt/conjugate base react and form molecules of weak acid.
• equilibrium lies well to the molecule side compared to the ions side of the equation.
• sodium salts are fully soluble and there will be a higher concentration of weak acid ions than there would be normally at equilibrium of the weak acid.
• reassociation of H^+ ions and weak acid negative ions to form molecules of weak acid</td></tr>
</table>

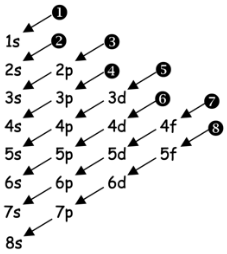
<table>
<tr><td>4a(iii)A</td><td>Buchner funnel with vacuum filtration</td><td>Vacuum filtration: filtration under reduced pressure
• faster means of separating a precipitate from a filtrate
Buchner, Hirsch or sintered glass funnel can be used.</td></tr>
<tr><td>4a(iii)B</td><td>To purify the hippuric acid</td><td>Recrystallisation: purify an impure solid with:
• dissolving an impure solid gently in a minimum volume of a hot solvent
• hot filtration of resulting mixture to remove any insoluble impurities
• cooling the filtrate slowly to allow crystals of the pure compound to form, leaving soluble impurities dissolved in the solvent
• filtering, washing and drying the pure crystals
solvent for recrystallisation is chosen so that the compound being purified is completely soluble at high temperatures and only sparingly soluble at lower temperatures.</td></tr>
<tr><td>4b(i)</td><td>Different atoms types in bonds and different strengths of bonds decides which wavelengths/ wavenumbers of infrared are absorbed.</td><td>When infrared radiation is absorbed by organic compounds, bonds within the molecule vibrate/stretch/bend
• wavelengths of infrared radiation absorbed depend on the type of atoms that make up the bond and the strength of the bond
• infrared radiation is passed through a sample of the organic compound and then into a detector that measures the intensity of the transmitted radiation at different wavelengths.
The absorbance of infrared radiation is measured in wavenumbers, measured in cm^{-1}</td></tr>
<tr><td>4b(ii)</td><td>3340 to 3400</td><td>Information found in data booklet.</td></tr>
<tr><td>4c(i)</td><td>6</td><td>
<table>
<tr><td>^{1}H Environment</td><td>Grouping</td></tr>
<tr><td>❶</td><td>ArH
(9.0-6.9)</td></tr>
<tr><td>❷</td><td>Amide link
(9.4-5.0)</td></tr>
<tr><td>❸</td><td>-CH$_2$-
(?)</td></tr>
<tr><td>❹</td><td>R-CH$_2$-COOH
(2.7-2.0)</td></tr>
</table>


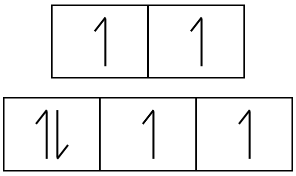
</td></tr>
<tr><td>4c(ii)</td><td>doublet</td><td>
<table>
<tr><td>singlet
no adjacent hydrogens</td><td>Doublet
1 adjacent hydrogen</td><td>Triplet
2 adjacent hydrogens</td><td>quartet
3 adjacent hydrogens</td><td>quintet
4 adjacent hydrogens</td></tr>
</table>
</td></tr>
<tr><td>4c(iii)</td><td>1st mark:
Hydrogen nuclei flip to align with magnetic field

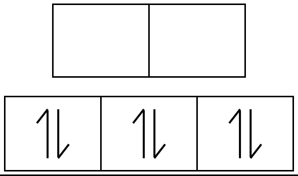
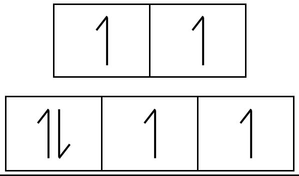
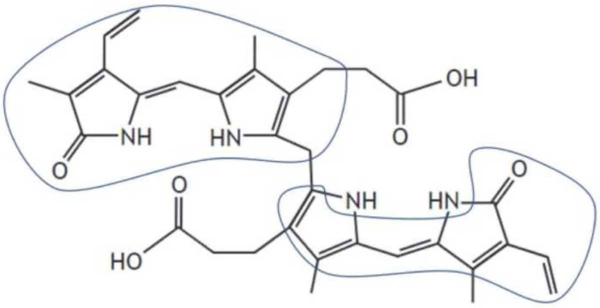
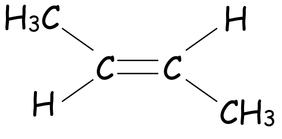
2nd mark:
Different energy for different hydrogen environments</td><td>^{1}H nuclei behave like tiny magnets and in a strong magnetic field some align with the field (lower energy), whilst the rest align against it (higher energy).
• Absorption of radiation in the radio frequency region of the electromagnetic spectrum causes the 1H nuclei to 'flip' from the lower to the higher energy alignment.
• As they fall back from the higher to the lower energy alignment the emitted radiation is detected and plotted on a spectrum.
• In a 1H NMR spectrum the chemical shift, δ , (peak position) is related to the environment of the 1H atom and is measured in parts per million (ppm).
The area under the peak is related to the number of 1H atoms in that environment and is often given by an integration curve on a spectrum. The height of an integration curve is proportional to the number of 1H atoms in that environment, and so a ratio of ^{1}H atoms in each environment can be determined.</td></tr>
<tr><td>4d</td><td>Open Question to include:</td><td>
<table>
<tr><td>3 mark answer</td><td>2 mark answer</td><td>1 mark answer</td></tr>
<tr><td>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.</td><td>Demonstrates a reasonable understanding of the chemistry involved, making some statement(s) which are relevant to the situation, showing that the problem is understood.</td><td>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.</td></tr>
</table>
</td></tr>
</table>

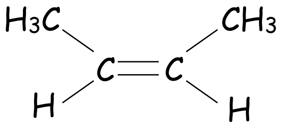
<table>
<tr>
<td>5a</td>
<td>Repulsion from electrons/lone pair</td>
<td>Ligands may be negative ions or molecules with non-bonding pairs of electrons that they donate to the central metal atom or ion, forming dative covalent bonds. Electrons in approaching ligands cause the splitting of d orbitals into higher and lower energies as the electrons along the axes to be repelled.

ligands that cause a large difference in energy between subsets of d orbitals are strong field ligands.
weak field ligands cause a small energy difference.
spectrochemical series is a list of ligands placed in order of their ability to split d orbitals
</td>
</tr>
<tr>
<td>5b(i)</td>
<td>Orbitals fill orbitals in order of increasing energy</td>
<td><u>Aufbau Principle</u>:
Electrons fill up in order of increasing energy:

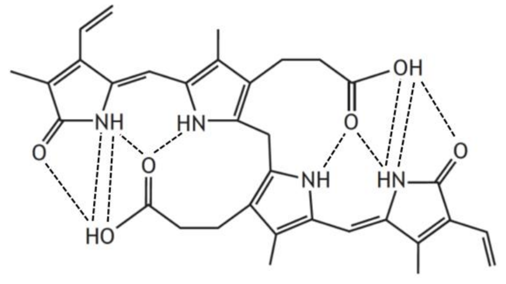
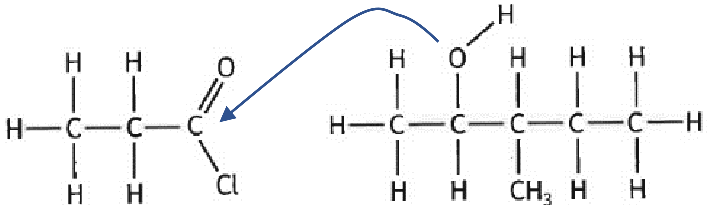
1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p 8s

</td>
</tr>
<tr>
<td>5b(ii)A</td>
<td>Both conclusions required:</td>
<td><table>
<tr>
<td>Conclusion 1

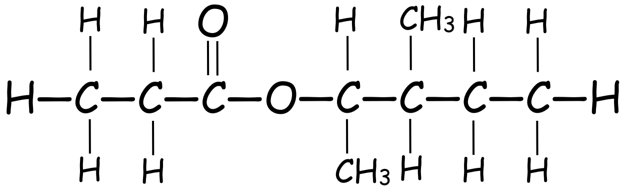
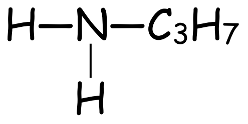
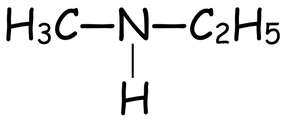
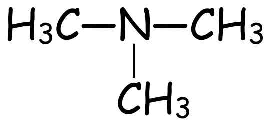
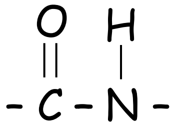
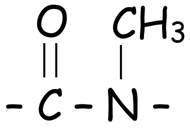
Higher charge of Cobalt in complex gives higher energy required to pair two electrons with opposite spin (P)</td>
<td><table>
<tr><td>Complex Ion</td><td>$[Co(OH_2)_6]^{2+}$</td><td>$[CoF_6]^{3-}$</td><td>$[Co(OH_2)_6]^{3+}$</td><td>$[Co(CN)_6]^{3-}$</td></tr>
<tr><td>Charge on Co</td><td>Co^{2+}</td><td>Co^{3+}</td><td>Co^{3+}</td><td>Co^{3+}</td></tr>
<tr><td>P (kJ mol^{-1})</td><td>250</td><td>283</td><td>283</td><td>283</td></tr>
</table></td>
</tr>
<tr>
<td>Conclusion 2:
Higher spin state has lower difference in energy between subsets of d orbitals (Δ)</td>
<td><table>
<tr><td>Δ (kJ mol^{-1})</td><td>111</td><td>156</td><td>323</td><td>416</td></tr>
<tr><td>Spin State</td><td>High</td><td>High</td><td>Low</td><td>Low</td></tr>
</table></td>
</tr>
</table></td>
</tr>
<tr>
<td>5b(ii)B</td>
<td>Hexafluoridocobaltate (III)</td>
<td>$$\underbrace{\text{Hexa}}_{\text{no. of ligands}}\underbrace{\text{fluorido}}_{F^-\text{ ligand}}\underbrace{\text{cobalt}}_{\text{metal name}}\underbrace{\text{ate}}_{\text{negative complex}}\underbrace{\text{(III)}}_{\text{charge on metal ion}} = [CoF_6]^{3-}$$
<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><u>Positive Complex</u>:
metals keep their name
<u>Negative Complex</u>:
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>5b(ii)C</td>
<td></td>
<td><table>
<tr><td>Electronic Configuration</td><td>Low Spin state of Co^{3+}</td><td>High Spin State of Co^{3+}</td></tr>
<tr>
<td>Element Cobalt Configuration:
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2$

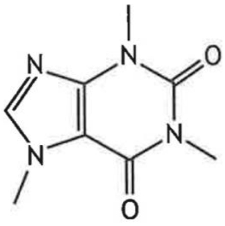
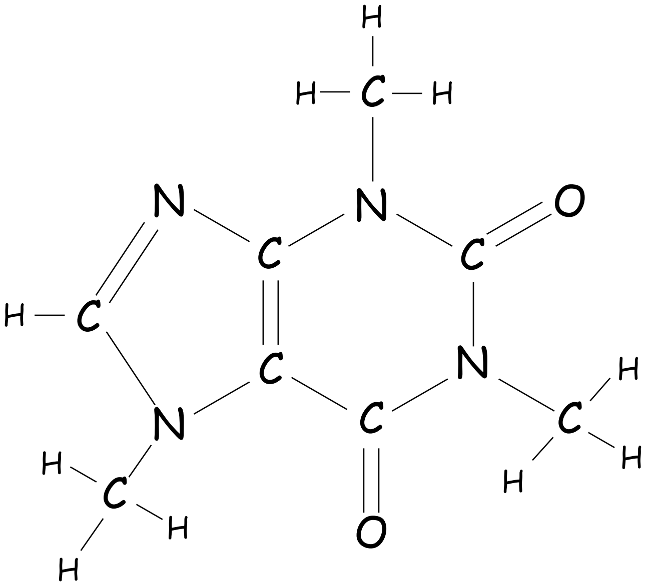
Cobalt Co^{3+} Ion Configuration:
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$</td>
<td></td>
<td></td>
</tr>
</table></td>
</tr>
<tr>
<td>6a(i)</td>
<td>Circled region of alternating C=C double bonds and C-C single bond.</td>
<td>
</td>
</tr>
<tr>
<td>6a(ii)</td>
<td>Antibonding molecular orbitals are higher in energy</td>
<td>Electrons fill bonding molecular orbitals, leaving higher energy antibonding molecular orbitals unfilled.</td>
</tr>
<tr>
<td>6b(i)</td>
<td>Answer to include:</td>
<td>C=C double bonds to not rotate around their axis to geometric isomers exist depending on the position of side groups in relation to C=C double bond.
<table>
<tr><td>$-CH_3$ methyl groups are on opposite sides of the C=C double bond</td><td>$-CH_3$ methyl groups are on same side of the C=C double bond</td></tr>
<tr>
<td>

trans-but-2-ene</td>
<td>

cis-but-2-ene</td>
</tr>
</table></td>
</tr>
</table>

6b(ii)	Dotted lines on diagram showing:	Dotted lines must be between: H of an N-H or O-H bond and O of a O-H bond or N of N-H bond 
6c(i)	Blue light provides enough energy to break bonds in bilirubin	Blue light has shorter wavelength than red light and has more energy.
6c(ii)	257.5	$E = \frac{L \times h \times c}{\lambda} = \frac{6.02\times10^{23}\ mol^{-1} \times 6.63\times10^{-34}\ J\ s \times 3\times10^{8}\ m\ s^{-1}}{465 \times 10^{-9} m}$ $= 257501\ J\ mol^{-1}$ $= 257.5\ kJ\ mol^{-1}$
7a(i)	Answer to include:	Place empty weighing bottle or weighing boat on balance. Record the mass of the empty item on balance. Add substance to boat/bottle on balance (careful not to spill any onto the top of balance). Record mass and subtract the empty mass to get mass of substance.
7a(ii)	0.0204	Absorbance = 0.42 ∴ $[MnO_4^-] = 2.1\times10^{-4}\ mol\ l^{-1}$ **no.** of mol = volume x **c**oncentration = $0.1_{litres} \times 2.1\times10^{-4}{}_{mol\ l^{-1}} = 0.000021mol$ **gfm** = 54.9g mass = no. of mol x gfm = $0.000021_{mol} \times 54.9_{g\ mol^{-1}} = 0.00115g$ $\%\ mass = \frac{0.00115}{5.66} \times 100 = 0.0204\%$
7b(i)	one from:	high state of purity be stable when solid and in solution be soluble reasonably high GFM
7b(ii)	0.358	**no.** of mol $Cr_2O_7^{2-}$ = **v**olume x **c**oncentration = $0.0214_{litres} \times 0.005_{mol\ l^{-1}} = 0.000107mol$ $6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \longrightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$ 6mol 1mol 0.000642mol 0.000107mol 25cm^3 Fe^{2+} solution = 0.000642mol 250cm^3 Fe^{2+} solution = 0.00642mol **gfm** Fe = 55.8g **mass** = **no.** of mol x **gfm** = $0.00642_{mol} \times 55.8_{g\ mol^{-1}} = 0.358g$
7b(iii)	Answer to contain:	1 mark *Green wavelengths absorbed turning HOMO into LUMO* 1mark *Green wavelengths absorbed ∴ red + blue wavelengths transmitted and purple light emitted*
8a	H_3PO_3 (any order of elements)	$3CH_3COOH + PCl_3 \longrightarrow 3CH_3COCl + H_3PO_3$
8b(i)	Negatively charged ions/neutral molecules that are electron rich	Nucleophiles are negatively charged ions or neutral molecules which are electron rich • attracted towards atoms bearing a partial δ+ or full positive charge • capable of donating an electron pair to form a new covalent bond Examples: Cl^-, Br^-, OH^-, CN^-, NH_3 and H_2O Electrophiles are positively charged ions or neutral molecules that are electron deficient • attracted towards atoms bearing a partial δ– or full negative charge • capable of accepting an electron pair to form a new covalent bond Examples: H^+ , NO_2^+ and SO_3
8b(ii)	Curly arrow from O on alcohol going to C of acid chloride group	

<table>
<tr><td>8b(iii)</td><td>Diagram showing:</td><td></td></tr>
<tr><td>8b(iv)</td><td>HCl</td><td>Condensation reactions join two molecules together and remove a small molecule as they join. Water is the most likely small molecule removed but hydrogen chloride HCl is removed in the condensation of alcohols and acid chloride to form esters.</td></tr>
<tr><td>8b(v)</td><td>Faster reaction or catalyst not required</td><td>As the equilibrium lies more to the product side in this reaction then more ester is produced at equilibrium</td></tr>
<tr><td>8c(i)</td><td>Secondary</td><td>
<table>
<tr><th>Primary Amine</th><th>Secondary Amine</th><th>Tertiary Amine</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>1 Carbon attached to the Nitrogen</td><td>2 Carbons attached to the Nitrogen</td><td>3 Carbons attached to the Nitrogen</td></tr>
</table>
</td></tr>
<tr><td>8c(ii)</td><td>amide</td><td>
<table>
<tr><td>Amide links have a carbonyl group attached to a nitrogen which can have one or two carbon groups attached to the nitrogen.</td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>8d(i)</td><td>Electrophilic substitution</td><td>$AlCl_3$ catalyst polarises the C-Cl bond in benzoyl chloride and the carbon end joins the benzene ring by electrophilic substitution.</td></tr>
<tr><td>8d(ii)</td><td>65.2%</td><td>
<table>
<tr><td>Benzoyl chloride
$\text{no. of mol} = \frac{\text{mass}}{\text{gfm}} = \frac{21.8}{140.5} = 0.155\text{mol}$</td><td>Benzophenone
$\text{no. of mol} = \frac{\text{mass}}{\text{gfm}} = \frac{18.4}{182} = \underset{\text{(actual)}}{0.101\text{mol}}$</td></tr>
</table>
benzoyl chloride + benzene ⟶ benzophenone + hydrogen chloride
1mol   1mol
0.155mol   0.155mol
(theoretical)
$\%\text{ Yield} = \frac{\text{Actual}}{\text{Theoretical}}\times100 = \frac{0.101\text{mol}}{0.155\text{mol}}\times100 = 65.2\%$
</td></tr>
<tr><td>9</td><td>Open Question to include:</td><td>
<table>
<tr><th>3 mark answer</th><th>2 mark answer</th><th>1 mark answer</th></tr>
<tr><td>Demonstrates a <u>good</u> 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.</td><td>Demonstrates a <u>reasonable</u> understanding of the chemistry involved, making some statement(s) which are relevant to the situation, showing that the problem is understood.</td><td>Demonstrates a <u>limited</u> 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.</td></tr>
</table>
</td></tr>
<tr><td>10a</td><td>Antagonist binds to receptor preventing the natural substrate from binding and stops natural response.</td><td>
<table>
<tr><td>agonist</td><td>An agonist mimics the natural compound and binds to the receptor molecules to produce a response similar to the natural active compound.</td></tr>
<tr><td>antagonist</td><td>An antagonist prevents the natural compound from binding to the receptor, and so blocks the natural response from occurring.</td></tr>
</table>
</td></tr>
<tr><td>10b(i)</td><td>$5cm^3$</td><td>A one in one hundred dilution requires a $5cm^3$ of eucalyptol transferred by pipette into a $500cm^3$ standard/volumetric flask and the filled up to the mark with deionised water.</td></tr>
<tr><td>10b(ii)</td><td>0.0598</td><td>mass = density x Volume = $0.921\,\text{g cm}^{-3} \times 5\text{cm}^3 = 4.605\text{g}$
$\text{no. of mol} = \frac{\text{mass}}{\text{gfm}} = \frac{4.605\text{ g}}{154\text{ g mol}^{-1}} = 0.0299\text{mol}$
$\text{concentration} = \frac{\text{no. of mol}}{\text{Volume}} = \frac{0.0299\text{ mol}}{0.500\text{ litres}} = 0.0598\text{mol l}^{-1}$</td></tr>
</table>

10b(iii)	6	no. of mol = Volume x concentration = $1_{\text{litre}} \times 9.97\times10^{-24}\,\text{mol l}^{-1} = 9.97\times10^{-24}\,\text{mol}$ $1\ \text{mol} = 6.02\times10^{23}$ molecules $9.97\times10^{-24}\,\text{mol} = 6.02\times10^{23}\ \text{molecules} \times \frac{9.97\times10^{-24}}{1}$ = 6.00 molecules
11a(i)	$C_8H_{10}N_4O_2$ (any order of elements)	 Skeletal Structure  Full Structural Formula
11a(ii)	Molecules must have similar shape to bind to same receptor protein	Pharmacologically active molecules must have a similar shape to fit the same receptor molecule. This common shape is called the pharmacophore. Agonists fit the receptor and produce the same biological response as the natural substrate. Antagonist fit the receptor but do not cause the biological response inside the cell.
11b(i)A	<u>1st mark</u>: separating funnel <u>2nd mark</u>: Shake/mix Leave to separate Run off lower layer	The steps of recrystallisation to purify an impure solid include: • dissolving an impure solid gently in a minimum volume of a hot solvent • hot filtration of the resulting mixture to remove any insoluble impurities • cooling the filtrate slowly to allow crystals of the pure compound to form, leaving soluble impurities dissolved in the solvent • filtering, washing and drying the pure crystals The solvent used for recrystallisation is chosen so that the compound being purified is completely soluble at high temperatures and only sparingly soluble at lower temperatures. The solvent used should be: • immiscible with the liquid mixture or solution (usually water) • one in which the solute is more soluble in than the liquid mixture or solution (usually water) • volatile to allow the solute to be obtained by evaporation of the solvent • unreactive with the solute
11b(i)B	4.61	$K = \frac{[\text{caffeine}]_{\text{dichloromethane}}}{[\text{caffeine}]_{\text{water}}} = \frac{23.5/60}{8.5/100} = \frac{0.392}{0.085} = 4.61$
11b(ii)	Do extraction in three separate volumes of $20\,\text{cm}^3$	The quantity of caffeine extracted is greater if a number of extractions using smaller volumes of solvent are carried out rather than a single extraction using a large volume of solvent.
11c	Diagram completed as shown: