Question Number	Correct Answer	Reject	Mark
1	D		**1**

Question Number	Correct Answer	Reject	Mark
2(a)	B		**1**

Question Number	Correct Answer	Reject	Mark
2(b)	B		**1**

Question Number	Correct Answer	Reject	Mark
2(c)	C		**1**

Question Number	Correct Answer	Reject	Mark
3	B		**1**

4(a)	B		**1**

Question Number	Correct Answer	Reject	Mark
4(b)	C		**1**

Question Number	Correct Answer	Reject	Mark
4(c)	D		**1**

Question Number	Correct Answer	Reject	Mark
4(d)	A		**1**

Question Number	Acceptable Answers	Reject	Mark
5(a)(i)	+89.6 – [+32.7 + 165] **(1)** = −108.1 J mol^{-1} K^{-1}/ J K^{-1} mol^{-1} Value, sign and **units** **(1)** Ignore SF except one Internal TE for recognisable numbers allowed, for example: $\Delta H^{\ominus}_{at}$ magnesium chloride (147.7→ -223.1) Halving $S^{\ominus}$ [Cl_2] (82.5 → -25.6) Correct answer with no working **(2)** +/no sign 108.1 J mol^{-1} K^{-1}/ J K^{-1} mol^{-1} **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
5(a)(ii)	(The sign is negative because) Any two from: • (A solid and) a gas reacting to form a solid. OR (Entropy decreases because) a gas reacting to form a solid. • There are fewer ways of arranging particles in a solid than a gas or vice-versa. OR Decrease in disorder as solid more ordered than gas or vice versa • Two mol(es) of reactant forming one mole of product. (Ignore two molecules form one molecule) OR Number of mol(es)/molecules decreases OR Fewer/less mol(es) of products than reactants	Energy... '(Positive) Answer is as expected...' **(0)**	**2**

Question Number	Correct Answer	Reject	Mark
5(b)	$\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{surroundings} + \Delta S^{\ominus}_{system}$ OR = +2152 + (-108.1) = (+)2043.9 Value 2043.9 / 2044 **(1)** = (+)2040 (J mol^{-1} K^{-1}) 3SF This mark conditional on correct value or correct TE value from (a)(i) **(1)** Accept TE from (a)(i), for example, -223.1 → +1928.9 → +1930 -25.6 → +2126.4 → +2130 Correct answer (2040, etc) with or without working scores 2		**2**

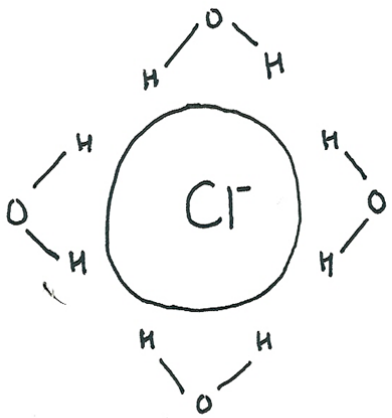
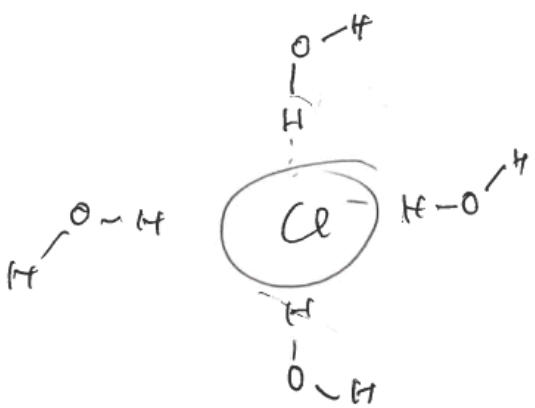
Question Number	Correct Answer1	Reject	Mark
5(c)	$\Delta S^{o}_{surroundings} = - \frac{\Delta H^{\ominus}}{298}$ $\Delta H^{\ominus} = - \Delta S^{\ominus}_{surroundings}$ x 298 OR $\Delta H^{\ominus} = -2152$ x 298 **(1)** $= -641.296$ $= -641.3$ (kJ mol^{-1}) **(1)** ALLOW $= -641.3 \times 10^{3}$ **J mol^{-1}** Note 1. -640.1338 = -640.1 (if 2040/answer to part (b) used to recalculate entropy change of surroundings first.) **(2)** 2. $\Delta H^{\ominus} = +641.3$ (kJ mol^{-1}) **(1)** 3. $\Delta H^{\ominus} = - \frac{\Delta S^{\ominus}_{surroundings}}{298}$ **(0)** Ignore SF except one		**2**

Question Number	Correct Answer	Reject	Mark
5(d)(i)	50 x 4.2 x 22.5 = 4725 (J) Ignore sign ALLOW 4.725 **kJ** Ignore SF except one		**1**

Question Number	Correct Answer	Reject	Mark
5(d)(ii)	There are two legitimate answers to this part. If **both** methods have been used, you **must** send the item to review under mark scheme (−)4725 ÷ 0.0300 = −157.5 (kJ mol^{-1}) /−157500 **J mol^{-1}** OR (−)4725 ÷ 0.0500 = /−94.5 (kJ mol^{-1}) /−94500 **J mol^{-1}** ALLOW TE answer (d)(i) ÷ 0.0300/0.0500 Ignore SF except one Value **(1)** Sign **(1)** The mark for the negative sign is awarded for their calculation even if value is wrong, providing any **energy divided by moles or energy multiplied by 1/number of moles** calculation has been done.		**2**

Question Number	Correct Answer	Reject	Mark
5(d)(iii)	There are two correct answers: Using 0.03 gives the answer of -381.75 kJ mol^{-1} Using 0.05 gives the answer of -350.25 kJ mol^{-1} Both these answers score full marks with or without correct working. **First mark** Appreciation of Hess's Law either in words, numbers, symbols or on the diagram For example, $\Delta H_{solution}$ + Lattice energy $= \Delta H_{hydration}\, Mg^{2+} + (2)\Delta H_{hydration}\, Cl^{-}$ **(1)** **Second mark** $2\ \Delta H_{hydration}\, Cl^{-} = -2526 - 157.5 - (-1920) = -763.5$ OR $2\ \Delta H_{hydration}\, Cl^{-} = -2526 - 94.5 - (-1920) = -700.5$ ALLOW Any number or group of numbers minus (-1920) **(1)** **Third mark** $\Delta H_{hydration}\, Cl^{-} = -381.75$ (kJ mol^{-1}) OR $\Delta H_{hydration}\, Cl^{-} = -350.25$ (kJ mol^{-1}) Any number, wherever it has come from,		**3**

	divided by two can score this mark, provided that the sign is consistent. **(1)** Ignore SF except one Use of lattice energy – 2326 gives −281.75/−250.25 scores **(2)** ALLOW TE from (d)(ii)		

Question Number	Correct Answer	Reject	Mark
5 (d)(iv)	 OR  • One/several water molecule(s) all correctly orientated. • $H^{\delta+}$/ hydrogen (one or two hydrogens from each water molecule) towards chloride ion • with negative charge either on chlorine or on the whole hydrated ion. ALLOW • A minus sign with a ring around it for the Cl^- • Bonds shown by lines/broken lines/dotted lines/wedges	**$Cl^-.H_2O$** $H^{\delta-}$ / H^+ / H^- $Cl^{\delta-}$ / Cl (with no charge)	**1**

Question Number	Correct Answer	Reject	Mark
5(d)(v)	Both marks may be awarded in either part. **First mark** (Temperature increases) because the reaction/process/dissolving/hydration of ions is **exothermic**. OR Strong(er) forces between the δ+ H and Cl^- OR Strong(er) forces between the δ– O and Mg^{2+} OR Strong(er) ion-dipole forces OR Formation of bonds releases energy OR Strong(er) bonds formed OR Enthalpy of hydration is greater than lattice energy **(1)** **Second mark** (Volume decreases so) shorter bonds between ion and water molecules ALLOW Water molecules more tightly arranged/pack better/occupy less space OR Water molecules more ordered/ clustered (around the ions). **(1)**	The breaking of the lattice is exothermic. Ions more tightly arranged Ions more ordered	**2**

Total for Question 9 = 17 marks

Section

Question Number	Correct Answer	Reject	Mark
6(a)(i)	Mass of ethanoic acid = 0.04 x 60.1 = (2.404 g) **(1)** Volume of ethanoic acid = 2.404 ÷ 1.049 = 2.2917 = 2.3 (cm^3) **(1)** Correct answer with no working **(2)** Ignore SF except only one ALLOW 60.0 for molar mass which gives mass 2.4 and volume 2.288 = 2.3 cm^3 **(2)** OR First step 1.049 ÷ 60/60.1 to find number of moles in 1 cm^3 = 0.017 **(1)** Then volume = 0.04 ÷ 0.017 = 2.3529 (cm^3) But note, if whole calculation done on calculator, 60 gives 2.2879 and 61 gives 2.2917. **(1)** If units given, they must be correct, but penalise wrong units only once here.		**2**

Question Number	Correct Answer	Reject	Mark
6 (a)(ii)	Syringe ALLOW Burette Graduated/adjustable pipette	Gas syringe Biuret Just 'pipette'	**1**

Question Number	Correct Answer	Reject	Mark
6(a)(iii)	To prevent… evaporation/vapour escaping water vapour entering OR To maintain a closed system OR To maintain a closed environment ALLOW To prevent: air oxidizing the alcohol reaction with air OR Due to volatility (of chemicals) IGNORE …gas escaping …HCl escaping		**1**

Question Number	Correct Answer	Reject	Mark
6(a)(iv)	**First and second mark** Phenolphthalein **(1)** From colourless to (pale) pink/red **(1)** ALLOW Other indicators with pK_{in} in range 7.5 – 10 Some examples are: Thymol blue ((base)) (yellow to blue) Phen**ol** red (yellow to red) Thymolphthalein (colourless to blue) Second mark depends on correct indicator except bromothymol blue, which is incorrect but very close to range so allow colour yellow to blue. **Third mark** Sodium ethanoate is (slightly) alkaline OR Ethanoic acid is a weak acid OR Phenolphthalein pH range coincides with vertical section of the pH/titration curve OR Titration of weak acid with strong base OR Neutralisation/equivalence point is at 8-10/ any number between 8 and 10. OR pK_{in} +/-1 lies within vertical region **(1)** Third mark is independent	Litmus/universal indicator Pink to colourless Thymol blue **(acid)** Phenyl red Methyl red	**3**

Question Number	Correct Answer	Reject	Mark
12 (b)(i)	$CH_3COOH+CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3+H_2O$ ALLOW Single arrow $-CO_2H$ $-C_2H_5$ Displayed formulae IGNORE state symbols even if incorrect		**1**

Question Number	Correct Answer	Reject	Mark
6(b)(ii)	Volume of alkali reacting with ethanoic acid = 77.1-11.7 = 65.4 cm^3 **(1)** Moles of ethanoic acid = $\frac{65.4 \times 0.200}{1000}$ = $0.01308/1.308\times10^{-2}$ (mol) **(1)** Correct answer no working (2) Ignore SF except 1 Allow internal TE for use of Moles of ethanoic acid = $\frac{77.1 \times 0.200}{1000}$ = $0.01542/1.542\times10^{-2}$ (mol) max**(1)**		**2**

Question Number	Correct Answer	Reject	Mark
6(b)(iii)	Number of moles of ethanol = $0.01308/1.308\times10^{-2}$ (mol) TE same as (ii)		**1**

Question Number	Correct Answer	Reject	Mark
6 (b)(iv)	Number of moles of ethyl ethanoate =0.0400−0.01308 = 0.02692 (mol) Allow TE from (ii)/(iii) for example 0.01542 gives 0.02458		**1**

Question Number	Correct Answer	Reject	Mark
(b)(v)	$K_c = \frac{[CH_3CO_2CH_2CH_3][H_2O]}{[CH_3CO_2H][CH_3CH_2OH]}$ **(1)** $= \frac{0.02692 \times 0.02692}{0.01308 \times 0.01308}$ = 4.23579 = 4.24 **(1)** Ignore SF except one Allow TE from (ii), (iii) and (iv) for example 0.01542 etc gives 2.54 No TE for incorrect expression of K_c		**2**

Question Number	Correct Answer	Reject	Mark
(b)(vi)	The units cancel OR There are the same numbers of moles of reactants and products		**1**

Question Number	Correct Answer	Reject	Mark
(b)(vii)	(Concentrated) hydrochloric acid contains water		**1**

Question Number	Correct Answer	Reject	Mark
6 (c)(i)	First test tube esterification OR addition/elimination ALLOW Condensation **(1)** Second test tube (acid) hydrolysis **(1)** Two fully correct answers in wrong order **(1) max**	Alkaline hydrolysis followed by acidification	**2**

Question Number	Correct Answer The values are the same within	Reject Just...the same	Mark **2**
6(c)(ii)	experimental error OR The values are concordant ALLOW The values are similar **(1)** The equilibrium can be approached from either direction OR The reaction is reversible OR Any comment relating equilibrium to reversibility IGNORE Dynamic equilibrium OR Rate of reverse reaction = rate of forward reaction **(1)**		

Question Number	Correct Answer	Reject	Mark
6 (c)(iii)	(Acid) catalyst (makes it faster) OR Provides H^+ (as a catalyst) OR Protonates... OR Protonating agent... OR Donates protons OR Increases H^+ concentration	Initiates Reacts with... Protates	**1**

Q13 (a) PENALISE USE OF CH_3COOH / 'ethanoic acid' [instead of propanoic acid] once only. ALLOW 'NaOH' for 'KOH', however.

Question Number	Correct Answer	Reject	Mark
7 (a)(i)	**Q13 (a) PENALISE USE OF CH_3COOH / 'ethanoic acid' [instead of propanoic acid] once only.** **ALLOW 'NaOH' for 'KOH', however.** **1st mark: Identification of buffer** **Any** mention of **buffer** / **buffering** (region) **(1)** IGNORE references to shape / gradient of graph **2nd mark: Identification of species present responsible for buffering action** (Both) propanoic acid **and** propanoate (ions) present OR (Both) propanoic acid **and** potassium propanoate present OR (Both) a **weak** acid and its salt/conjugate base are present OR (Both) CH_3CH_2COOH **and** $CH_3CH_2COO^-$ present OR (Both) HA and A^- are present **Can be awarded from an equation** **(1)**		**3**

	3rd mark: Two routes for this mark: **1st route:** **For how these species were formed** **OR** **alternatively** **2nd route:** **For mention of how this buffer works, on small additions of OH^-** **1st ROUTE to 3rd mark** $CH_3CH_2COOH + OH^- \rightarrow H_2O + CH_3CH_2COO^-$ OR In words, **excess** CH_3CH_2COOH is left / some CH_3CH_2COOH has reacted with potassium hydroxide / KOH / OH^- (forming propanoate ions) **2nd ROUTE – buffering action** On addition of OH^- (in small quantities) H^+ ions react with (the added) OH^- **and** (the equilibrium) $CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H^+$ shifts to the **right** OR (the reservoir of undissociated) CH_3CH_2COOH molecules react with (the added) OH^- **NOTE:** For the 2nd route "OR" mark here, this statement/equation must be in the context of buffering action **IGNORE** References to buffering action on addition of H^+ ions (not relevant here) **(1)**		

Question Number	Correct Answer	Reject	Mark
7(a) (ii)	**1st scoring point:** Propanoate ions present (at equivalence point) OR Potassium propanoate present (at equivalence point) **(1)** **2nd scoring point:** Propanoate (ions) react with water / propanoate (ions) are hydrolysed by water / $CH_3CH_2COO^-$ ions react with water ALLOW propanoate ions react with H^+ (from water) / the salt reacts with water (molecules) **(1)** **3rd scoring point – consequential on 2nd scoring point being awarded:** Forming hydroxide ions/ leaves excess of hydroxide ions / produces OH^- / forming OH^- / forming KOH / $[OH^-] > [H^+]$ **(1)** **NOTE – the equation:** $CH_3CH_2COO^- + H_2O \rightarrow OH^- + CH_3CH_2COOH$ **OR** $CH_3CH_2COOK + H_2O \rightarrow KOH + CH_3CH_2COOH$ scores **ALL THREE MARKS** **NOTE** **Just** 'weak acid – strong base titration' scores **(1) only**		**3**

Question Number	Correct Answer	Reject	Mark
7(a) (iii)	**[FIRST, CHECK THE FINAL ANSWER IF ANSWER pH = 12(.02), award 5 marks]** Moles of acid used = 25/1000 x 0.024 OR moles of acid used = 6×10^{-4} (mol) **and** Moles of alkali added = 40/1000 x 0.032 OR Moles of alkali added = 1.28×10^{-3} (mol) **(1)** Moles of excess alkali = $1.28 \times 10^{-3} - 6 \times 10^{-4}$ OR Moles of excess alkali = 6.8×10^{-4} (mol) **(1)** $[OH^-] = 6.8 \times 10^{-4} / (65/1000)$ $= 0.01046$ (mol dm^{-3}) **(1)** Allow TE from incorrect moles of acid or alkali, **provided the alkali moles are in excess** $[H^+] = 1 \times 10^{-14} / 0.01046$ $= 9.56 \times 10^{-13}$ (mol dm^{-3}) **(1)** Allow TE from incorrect moles of excess alkali or the candidate's value of $[OH^-]$. Must use K_w value here to get $[H^+]$ pH = $-\log 9.56 \times 10^{-13}$ = 12(.02) **(1)** Can get M4 and M5 using pH + pOH = 14 Allow TE from incorrect $[H^+]$ for M5, but their CQ pH must **>** 7 IGNORE S.F. EXCEPT 1 SF		**5**

	NOTE If fail to **÷ by 0.065 dm^3**, then pH = 10.8 scores 4 marks. Other answers to look for if M1 and M2 have been awarded, but division by an incorrect value for the total volume of the mixture, then each of the following would score 4 overall as shown. **If ÷ by 0.025 dm^3, no M3** pH = 12(.43) scores 4 marks. **If ÷ by 0.040 dm^3, no M3** pH = 12(.23) scores 4 marks. **If ÷ by 0.015 dm^3, no M3** pH = 12(.66) scores 4 marks.		

Question Number	Correct Answer	Reject	Mark
7(b)	No, as T increases eqm moves to RHS / K_w increases / 'favours RHS' / ΔS_{total} increases **(1)** So $[H^+]$ ions increases / more H^+ ions $[H^+]$ **>** 1 x 10^{-7} **(1)** Hence pH < 7 / pH decreases **(1)** **OR** reverse argument for a decrease in temperature **NOTE** If answer given is 'Yes' (i.e. candidate thinks that the pH of pure water **is** always 7.0), then max **(1)** for stating that equilibrium shifts to the right when temperature increases (since reaction is endothermic in the forward direction) **NOTE** If says K_w **decreases** as T increases, then max **(1)** for a completely logical CQ argument mentioning the effect on $[H^+]$ (decreasing) **and** pH (increasing)		**3**

(TOTAL FOR QUESTION 13 = 14 marks)

Section C

<table>
<tr><th>Question Number</th><th>Correct Answer</th><th>Reject</th><th>Mark</th></tr>
<tr><td>8 (a)(i)</td><td>
<table>
<tr><td></td><td>$CH_2CHCHCH_2$</td><td>CO</td><td>H_2O</td><td>$HOOC(CH_2)_4COOH$</td></tr>
<tr><td>ΔH_f / kJ mol^{-1}</td><td>+109.9</td><td>−110.5</td><td>−285.8</td><td>−994.3</td></tr>
<tr><td>S / J mol^{-1} K^{-1}</td><td>278.7</td><td>197.6</td><td>69.9</td><td>250.0</td></tr>
</table>
4 values correct (2) marks

3 / 2 values correct (1) mark

0 / 1 values correct (0) marks
</td><td></td><td>2</td></tr>
</table>

Question Number	Correct Answer	Reject	Mark
8 (a)(ii)	−994.3 − [+109.9 + (2 x −110.5) + (2 x −285.8)] **(1)** = − 311.6 (kJ mol^{-1}) **(1)** Allow TE from (a) **NOTE** If both −110.5 and −285.8 are not doubled, answer CQ = −707.9 (kJ mol^{-1}) for **1** mark Ignore SF except 1 SF		**2**

Question Number	Correct Answer	Reject	Mark
8 (a)(iii)	250(.0) − [278.7 + (2 x 197.6) + (2 x 69.9)] **(1)** = −563.7 (J mol^{-1} K^{-1}) **(1)** Allow TE from (a) **NOTE** If both 197.6 and 69.9 are not doubled, answer CQ = −296.2 (J mol^{-1} K^{-1}) for **1** mark Ignore SF except 1 SF		**2**

Question Number	Correct Answer	Reject	Mark
8 (a)(iv)	ΔS_{surr} at 298 K = $-\Delta H/T$ **(1)** = − (−311.6 x 1000) / 298 = (+) **1045.6** (J mol^{-1} K^{-1}) Allow TE from (a)(ii) e.g. ΔS_{surr} = (+)2375.5(0) (J mol^{-1} K^{-1}) scores (2) if no doubling in (a)(ii) **(1)** $\Delta S_{tot} = \Delta S_{surr} + \Delta S_{sys}$ / ΔS_{tot} = 1045.6 −563.7 / ΔS_{tot} = (+) **481.9** (J mol^{-1} K^{-1}) Allow TE from (a)(ii) and (a)(iii) **(1)** Allow correct answers given in **kJ mol^{-1} K^{-1}** e.g. 0.4819 **kJ mol^{-1} K^{-1}** Ignore SF except 1 SF If candidates forget to convert ΔH into J mol^{-1}, then ΔS_{tot} = −562.7 (J mol^{-1} K^{-1}) would score (2) if correct working is included		**3**

Question Number	Correct Answer	Reject	Mark
8 (a)(v)	(Decrease in T) **1st mark: consideration of ΔS_{system}** ΔS_{system} is not (significantly) changed / is unchanged / remains (approximately) constant **(1)** **2nd mark: consideration of ΔS_{surr}** ΔS_{surr} or $-\Delta H/T$ is more positive / larger / greater COMMENT ALLOW 'less negative' **(1)** **3rd mark: consideration of ΔS_{total}** (So) increases ΔS_{tot} / makes ΔS_{tot} more positive / makes ΔS_{tot} greater **(1)** **NOTE** IF no reference / an incorrect reference made to ΔS_{system}, then only the 2nd and 3rd marks can be awarded **NOTE** If candidate states that ΔS_{surr} becomes **less +ve**, no M2 But if **then** states CQ that ΔS_{tot} decreases award M3 as a TE		**3**

Question Number	Correct Answer	Reject	Mark
8 (b)	**DIMINISHING:** (Peak between) **1669 – 1645** (cm^{-1}) (due to C=C) **OR** (Peak between) **3095 – 3010** (cm^{-1}) (due to alkene C-H) **(1)** **INCREASING:** (Peak between) **1725 – 1700** (cm^{-1}) (due to C=O in carboxylic acid) **OR** (Peaks due to alkane C–H bonds at) EITHER **2962 – 2853** (cm^{-1}) OR **1485** – **1365** (cm^{-1}) **ALLOW** (Peak between) **3300 – 2500** (cm^{-1}) (due to O–H in carboxylic acid) **(1)**	**1740 – 1720** **3750 – 3200**	**2**

Question Number	Correct Answer	Reject	Mark
8 (c)	(Makes it taste) sour / sharp / tart IGNORE 'acidic' / 'bitter' NOTE Contradictory answers (e.g. 'sharp and sweeter') score **(0)**	fruity sweet(er) none	**1**

Question Number	Correct Answer	Reject	Mark
8(d) (i)	**1st mark:** (% of oxygen =) **43.9** (%) **(1)** **2nd mark:** Amount of C = 49.3/12 = 4.1 (mol) Amount of H = 6.8/1 = 6.8 (mol) Amount of O = 43.9/16 = 2.7 (mol) **(1)** **3rd mark:** Ratio **1.5 C : 2.5 H : 1 O** (≡3 C : 5 H : 2 O) ALLOW for 3rd mark:- Decimal values that round up to these values (e.g. **1.497 C : 2.478 H : 1 O** scores the 3rd mark) **(1)** **ALLOW** M_r of $C_3H_5O_2$ = 73 (g mol^{-1}) **(1)** %C = $\frac{36}{73}$ x 100 = 49.3% **and** %H = $\frac{5}{73}$ x 100 = 6.8% **(1)** %O = 43.9% ALLOW 43.8% **(1)**		**3**

<table>
<tr><th>Question Number</th><th>Correct Answer</th><th>Reject</th><th>Mark</th></tr>
<tr><td>8(d)
(ii)</td><td>For ‘Chemical shift’ column, allow any range or any single value within range
<table>
<tr><th>Feature of compound Q</th><th>Chemical shift / ppm</th><th>Splitting pattern</th></tr>
<tr><td>CH_3</td><td>0.1 – 1.9</td><td>Triplet (1)
Allow (splits into) three</td></tr>
<tr><td>CH_2</td><td>1.7 – 3(.0) (1)</td><td>Quartet (1)
Allow quadruplet / (splits into) four</td></tr>
<tr><td>OH</td><td>10(.0) – 12(.0) (1)</td><td>singlet</td></tr>
</table></td><td></td><td>4</td></tr>
</table>