Section A

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

Question Number	Correct Answer	Reject	Mark
2	C		**1**

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

Question Number	Correct Answer	Reject	Mark
4	A		**1**

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

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

Question 7: N/A

Question Number	Correct Answer	Reject	Mark
8	A		**1**

Question Number	Correct Answer	Reject	Mark
9	A		**1**

Question 10: N/A
Question 11: N/A
Question 12: N/A

Question Number	Correct Answer	Reject	Mark
13	A		**1**

Question 14: N/A
Question 15: N/A

Question Number	Correct Answer	Reject	Mark
16	C		**1**

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

Question 18: N/A

Question Number	Correct Answer	Reject	Mark
19	C		**1**

Question Number	Correct Answer	Reject	Mark
20	C		**1**

Section B

Question Number	Acceptable Answers	Reject	Mark
21 (a)(i)	(pH =) -log [H^+] OR (pH =) -log [H_3O^+] OR **Accept** Definition in words (For example: "It is minus / negative log(arithm) of the hydrogen **ion** concentration") Base 10 does not have to be there, but reject "**ln**"	**Just** "concentration of hydrogen ions" { } curly brackets -log H^+	**1**

Question Number	Acceptable Answers	Reject	Mark
21 (a)(ii)	(pH = -log 0.0100) = 2(.00)	If any units given	**1**

Question Number	Acceptable Answers	Reject	Mark
21 (b)(i)	$[H_3O^+] = \frac{K_a[CH_3COOH]}{[CH_3COO^-]}$ OR $[H_3O^+]^2 = K_a[CH_3COOH]$ **(1)** *ALLOW* [HA] for $[CH_3COOH]$ and $[A^-]$ for $[CH_3COO^-]$ in rearranged expression **Accept** $[H^+]$ for $[H_3O^+]$ $\therefore [H_3O^+] = \sqrt{}\ 1.75 \times 10^{-7}$ OR $\therefore\ [H_3O^+] = 4.18(3) \times 10^{-4}$ (mol dm^{-3}) **(1)** pH = 3.38 / 3.4 **(1)** ignore sf except one sf Third mark TE from $[H^+]$ only if pH **less than 7** ***N.B. CORRECT ANSWER, WITH OR WITHOUT WORKING, SCORES (3)*** **Assumption** assumes that degree of ionisation of the acid is very small/negligible OR $[CH_3COOH]_{eqm} = [CH_3COOH]_{initial}$ OR $[H^+] = [CH_3COO^-]$ OR all of the hydrogen **ions** come from the acid / ignore hydrogen ions from the water **(1)** *IGNORE* any references to temperature	3.37 / 3 /3.39 / a correct pH value **with units** just "weak acid" / just "partially dissociates" / acid does not dissociate / $[CH_3COOH]$ **constant** $[H^+] = [OH^-]$ / $[H^+]$ = [salt]	**4**

Question Number	Acceptable Answers	Reject	Mark
21 (b)(ii)	**First mark:** (Dilution/addition of water) shifts the equilibrium $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ / $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ to the **right** OR the above stated in words such as: degree of dissociation increases/ proportion of dissociation increases/ more dissociation (as the ethanoic acid is diluted) **(1)** **Second mark:** so the $[H^+]$ is greater than expected/ so the decrease in $[H^+]$ is less than expected / so that the decrease in $[H^+]$ is less than that for hydrochloric acid **(1)** **Each mark is a stand alone mark.** *ALTERNATIVE ROUTE:* **First mark:** $[H^+] = \sqrt{K_a \times [HA]}$ OR $(K_a \times [HA])^{\frac{1}{2}}$ OR $pH = \frac{1}{2}pK_a - \frac{1}{2}\log[HA]$ **(1)** **Second mark:** use of mathematical expression given (e.g.$[H^+]$ affected by factor of $1/\sqrt{10}$ on dilution OR substitution of numerical values into the equation) **(1)** *IGNORE:* any comments or calculations relating to HCl(aq)	Reject just a reference to a 0.5 increase in pH for $CH_3COOH(aq)$ compared with a 1.0 increase in pH for HCl(aq)	**2**

Question Number	Acceptable Answers	Reject	Mark
21 (c)(i)	**These marks are stand alone.** Maintains an **almost** constant pH / resists change(s) in pH **(1)** for **small** addition of H^+ or OH^- ions (N.B. both ions needed) / for **small** additions of acid or alkali / for **small** additions of acid or base **(1)** *IGNORE* any references to named buffer mixtures	"resists small change(s) in pH" OR "pH does not change"	**2**

Question Number	Acceptable Answers	Reject	Mark
21 (c)(ii)	citric acid		**1**

Question Number	Acceptable Answers	Reject	Mark
21 (c)(iii)	**First mark:** (buffer contains) reservoir of HA **and** A^- OR (buffer contains) large concentrations of [HA] **and** $[A^-]$ OR **both** equations: $HA \rightleftharpoons A^- + H^+$ **and** $NaA \rightarrow Na^+ + A^-$ **(1)** **Second mark:** (Addition of alkali/base) $HA + OH^- \rightarrow A^- + H_2O$ OR description/equations to show that H^+ reacts with OH^- (to form H_2O) and more acid dissociates (to replace H^+) **(1)** **Third mark:** (Addition of acid) $A^- + H^+ \rightarrow HA$ OR A^- reacting with H^+ in any context described in words (e.g. by reference to weak acid equilibrium) **(1)** **Fourth mark:** the ratio of $[A^-] \div [HA]$ hardly changes / the ratio of $[HA] \div [A^-]$ hardly changes OR $[A^-]$ nor [HA] changes **significantly (1)**	**JUST** $NaA \rightleftharpoons Na^+ + A^-$ and $HA \rightarrow H^+ + A^-$ without correct description **Just** $[H^+]$ remains constant	**4**

Question 22: N/A

Question Number	Acceptable Answers	Reject	Mark
23 (a)(i)	**These are stand alone marks** **First mark:** (ensures that) $[H^+]$ **and** [propanone] (virtually) constant OR so that the $[H^+]$ **and** [propanone] do not affect the rate **(1)** **Second mark:** the $[I_2]$ / iodine concentration changes OR so that the **overall** order (of reaction) is **not** determined OR otherwise a curve (graph) is obtained **(1)** ***NOTE:-*** "**only** the $[I_2]$ changes **scores (2)** **OR** "**only** the I_2 concentration changes" **scores (2)** **BUT** "only the iodine changes" **scores (1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
23 (a)(ii)	**First mark:** **double** the concentration of propanone *OR* change/increase/decrease the concentration of propanone **(1)** **Second mark (mark consequentially):** slope/gradient of line **doubles** *ALLOW* "rate doubles" *OR* slope or gradient changes/increases/decreases by same factor *ALLOW* "rate changes/increases/decreases by same factor" **(1)** ***NOTE:*** **may suggest a different procedure**:- **First mark:** monitor/measure [propanone] over time **(1)** **Second mark (mark consequentially):** plot [propanone] v. time graph **and** state that $t_{½}$ constant **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
23 (a)(iii)	I_2 not involved in rate-determining step/ I_2 not involved in slow(est) step / H^+ and propanone involved in rate-determining step/ H^+ and propanone involved in slow(est)step **(1)** so there must be another step where I_2 is involved/ so there must be a fast step where I_2 is involved **(1)** ***BUT*:-** I_2 not involved until **after** the rate-determining step/ I_2 not involved until **after** the slow(est) step **(2)** *ALLOW* H^+ involved in rate-determining step **(1)** and is regenerated as it is a catalyst (in another step) **(1)**	I_2 involved **before** rate-determining/slowest step **(0)**	**2**

Question Number	Acceptable Answers	Reject	Mark
23 (b)(i)	$HCO_3^- + H^+ \rightarrow H_2O + CO_2$ OR $HCO_3^- + H^+ \rightarrow H_2CO_3$ OR $HCO_3^- + H_3O^+ \rightarrow 2H_2O + CO_2$ OR $HCO_3^- + H_3O^+ \rightarrow H_2CO_3 + H_2O$ *ALLOW:* $NaHCO_3 + H^+ \rightarrow Na^+ + H_2O + CO_2$ OR $Na^+ + HCO_3^- + H^+ \rightarrow Na^+ + H_2O + CO_2$ *IGNORE* any correct or any incorrect state symbols	$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$ OR any equations with HA	**1**

Question Number	Acceptable Answers	Reject	Mark
23 (b)(ii)	$CH_3COCH_3 + \mathbf{3}I_2 + \mathbf{4}NaOH \rightarrow CHI_3 + CH_3COONa + \mathbf{3}NaI + \mathbf{3}H_2O$ *IGNORE* any correct or any incorrect state symbols **CHI_3** on RHS of equation **(1)** remaining species correct **(1)** balanced equation **(1)** ***NOTE:*** balancing mark is CQ on all species correct **Accept** correct ionic equation (i.e. Na^+ omitted) NOTE: If **CH_3I**, can only access second mark above		**3**

Question Number	Acceptable Answers	Reject	Mark
24 (a)	$K_p = \frac{p(H_2)^3\ p(CO)}{p(CH_4)p(H_2O)}$ **(1)** Brackets not required	**[ ]** $K_p = \frac{p(H_2)^3 + p(CO)}{p(CH_4) + p(H_2O)}$	**1**

Question Number	Acceptable Answers	Reject	Mark
24 (b)(i)	No effect (as K_p dependent only on temperature) **(1)**		**1**

Question Number	Acceptable Answers	Reject	Mark
24 (b)(ii)	**(**Since $K_p = \frac{x(H_2)^3\ x(CO)}{x(CH_4)x(H_2O)} \times \frac{P_T^4}{P_T^2}$ to maintain K_p constant, mole fractions of numerator must decrease OR mole fractions of denominator must increase as $\times P_T^2$ overall**)** **First mark:** *EITHER* mole fractions/partial pressures of numerator decrease *OR* mole fractions/partial pressures of denominator increase **(1)** **Second mark:** any mention of $\times P_T^2$ OR $\times \frac{P_T^4}{P_T^2}$ **(1)** *ALLOW* ***P*** for P_T **NOTE:** **If Le Chatelier quoted, statements such as:** "Equilibrium shifts to side of fewer moles (of gas molecules)/fewer (gas) molecules" **max (1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
24 (b)(iii)	Reaction takes place on **surface** of the catalyst **(1)** Active sites/(catalyst) surface is saturated with reactant molecules/reactants (at the pressure of the reaction) **(1)** *NOTE:* an answer such as "... depends on the availability of active sites on catalyst surface" scores **(2)**		**2**

Question Number	Acceptable Answers	Reject	Mark
24 (c)	$CO + H_2O \rightleftharpoons CO_2 + H_2$ **initial: 1, 1, 0, 0** **eq'm: 0.25, 0.25, 0.75, 0.75** **mol frac: 0.125, 0.125, 0.375, 0.375** **pp: 3.75, 3.75, 11.25, 11.25** • eq'm moles all correct **(1)** • mole fractions all correct **(1)** • partial pressures and answer = 9 **with no units** **(1)** *NOTE:* **3rd** mark not awarded if any units shown *NOTE:* $\frac{11.25^2}{3.75^2}$ = 9 **scores (3)** *NOTE:* Mark each step CQ. **CHECK ALL WORKING**		**3**

Question Number	Acceptable Answers	Reject	Mark
24 (d)(i)	production (of hydrogen) forms CO_2 OR production (of hydrogen) forms a Greenhouse gas OR production (of hydrogen) forms CO OR CO_2 is a Greenhouse gas OR CO is a Greenhouse gas ALLOW production (of hydrogen) uses/requires energy *ALLOW* CO is toxic/poisonous	methane **produced (0)**	**1**

Question Number	Acceptable Answers	Reject	Mark
24 (d)(ii)	$2KHCO_3 \rightarrow K_2CO_3 + CO_2 + H_2O$ *ALLOW* multiples		**1**

Question Number	Acceptable Answers	Reject	Mark
24 (e)	products removed OR not a closed system OR balance between rate and yield OR balance between time and yield OR recycling of reactants OR more product in unit time (so process more economically viable) *IGNORE* any comments relating to cost	references to atom economy dangers of maintaining high pressures	**1**

Section C

Question Number	Acceptable Answers	Reject	Mark
25 (a)	ΔS^{o}_{total} is positive / $\Delta S^{o}_{total} > 0$ with or without superscript *NOTE:* **This mark may be awarded from answer to Q25(b)(v)** **Accept** ΔG^{o} is negative	**Just** "the entropy is positive"	**1**

Question Number	Acceptable Answers	Reject	Mark
25 (b)(i)	(+)27.3 **and** (+)87.4 (J mol^{-1} K^{-1}) *IGNORE* incorrect units		**1**

Question Number	Acceptable Answers	Reject	Mark
25 (b)(ii)	ΔS^{o}_{sys} = (2x87.4) – {(4x27.3 + (3x205.0)} **(1)** = −549.4 / −549(J mol^{-1} K^{-1}) **(1)** Correct answer with or without correct units **(2)** *IGNORE any wrong units* **Accept** TE from (b)(i) *NOTE:* +549/+549.4 scores **(1)** **Check working** *NOTE:* 1st mark: for x2, x4 and x3 2nd mark: for (products – reactants), with correct arithmetic		**2**

Question Number	Acceptable Answers	Reject	Mark
25 (b)(iii)	$\Delta S_{surr} = -\frac{\Delta H}{T}$ $= -(-1648 \times 10^3) \div 298(.15)$ (J mol^{-1} K^{-1}) = (+) 5530 (J mol^{-1} K^{-1}) OR = (+) 5.53 **kJ mol^{-1} K^{-1}** **(1)** *NOTES:* • Correct answer, with or without working, scores **(1)** • If **5530** (J mol^{-1} K^{-1}) given, **IGNORE** any subsequent incorrect attempts to convert it to a value in kJ mol^{-1} K^{-1} *IGNORE* s.f. except one s.f.	**Just** (+)5.53 with no units OR (+)5.53 **kJ mol^{-1}**	**1**

Question Number	Acceptable Answers	Reject	Mark
25 (b)(iv)	ΔS_{total} = (-549.4) +(+5530) = +4980.6/+ 4981 **J mol^{-1} K^{-1}** OR +4.981 **kJ mol^{-1} K^{-1}** **(1)** for value **(1)** for correct sign **and** units *IGNORE* s.f. except one s.f. **Accept** TE from (b)(ii) and (b)(iii)	**Just** the formula: $\Delta S_{total} = \Delta S^{o}_{sys} + \Delta S_{surr}$	**2**

Question Number	Acceptable Answers	Reject	Mark
25 (b)(v)	(ΔS_{system} is negative): as loss of disorder as gas → solid OR more order as gas → solid OR as decrease in entropy as gas → solid **(1)** (ΔS_{surr} is positive): (heat) energy released (increases kinetic energy and hence movement of the surrounding molecules) **(1)** ΔS_{total} is positive because ΔS_{surr} is (numerically) greater than ΔS_{sys} OR ΔS_{surr} "outweighs" ΔS_{sys} OR ΔS_{surr} sufficiently large so that ΔS_{total} is positive **(1)**	**Just** "reaction is exothermic" ΔS_{total} is negative **(0)** for third scoring point	**3**