Section A (multiple choice)

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

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

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

Question Number	Correct Answer	Reject	Mark
4(a)	B		**1**
(b)	D		**1**

Question Number	Correct Answer	Reject	Mark
5(a)	B		**1**
(b)	C		**1**
(c)	B		**1**

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

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

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

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

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

Question 11: N/A

Question 11: N/A

Question 12: N/A

Question 13: N/A

Question 14: N/A

Question 15: N/A

Question 16: N/A

Section B

Question Number	Acceptable Answers	Reject	Mark
17(a)	Units are not required in (a) or (c) but if used should be correct. Penalise incorrect units in (a), (b) & (c) once only IGNORE case of J and K order of units **First mark:** 65.3/ 130.6 **and** 69.9 (J mol^{-1} K^{-1}) **(1)** **Second mark:** ΔS = 69.9 − (130.6 +102.5) **(1)** **Third mark:** ΔS = −163.2 = −163 (J mol^{-1} K^{-1}) **(1)** Correct answer with no working scores 3 Ignore SF except 1 SF TE at each stage If 65.3 used instead of 130.6 penalize once (answer is then ΔS = −97.9 (J mol^{-1} K^{-1})	+163 or any positive answer	**3**

Question Number	Acceptable Answers	Reject	Mark
17(b)	$\Delta S_{surroundings}$ = − ΔH / T or just numbers **(1)** = +285800/298 = +959.06 = +959 J mol^{-1} K^{-1} / +0.959 kJ mol^{-1} K^{-1} Correct value to 3SF **(1)** Correct units and positive sign **(1)** Correct answer with no working scores 3	answer with no sign	**3**

Question Number	Acceptable Answers	Reject	Mark
17(c)	$\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$ **(1)** Allow $\Delta S_{reaction}$ for ΔS_{system} ΔS_{total} = answer (a) + answer (b) = −163.2 + 959 = (+)795.8 = (+)796 (J mol^{-1} K^{-1}) If $\Delta S_{surroundings}$=+959.06 then ΔS_{total} = +795.9 **(1)** Correct answer with no working scores 2 Ignore SF except 1 SF TE on values in (a) & (b) no TE on incorrect equation If answer to (a) = -97.9 (J mol^{-1} K^{-1}) ΔS_{total} = (+)861.1 (J mol^{-1} K^{-1})		**2**

Question Number	Acceptable Answers	Reject	Mark
17(d)	A mixture of hydrogen and oxygen is **thermodynamically** unstable **because** ΔS_{total} is positive OR Reaction between hydrogen and oxygen is **thermodynamically** feasible **because** ΔS_{total} is positive ALLOW ΔS for ΔS_{total} **(1)** No TE on negative ΔS_{total} from (c) The mixture is kinetically inert /stable or reaction is (very) slow **because** the activation energy is (very) high **(1)** Mixture / reaction is **kinetically** inert / stable but **thermodynamically** unstable / feasible scores 1 mark IGNORE References to spark / flame providing the (activation) energy for reaction	Reference to the stability of individual elements	**2**

Total for Question 17 = 10 Marks

Question Number	Acceptable Answers	Reject	Mark
18(a)(i)	$HC_2O_4^-(aq) + H_2O(l) \rightleftharpoons C_2O_4^{2-}(aq) + H_3O^+(aq)$ (or →) ALLOW $H_2O(aq)$ Equation **(1)** states **(1)** ALLOW for 1 mark $HC_2O_4^-(aq) \rightleftharpoons C_2O_4^{2-}(aq) + H^+(aq)$ States mark is not stand alone but can be awarded if the equation has a minor error e.g. an incorrect charge		**2**

Question Number	Acceptable Answers	Reject	Mark
18(a)(ii)	$K_a = [C_2O_4^{2-}][H_3O^+] / [HC_2O_4^-]$ OR $K_a = [C_2O_4^{2-}][H^+] / [HC_2O_4^-]$ No TE on incorrect equation in (a)(i) Penalise incorrect charges in (i) and (ii) once only	$K_a =$ $[H^+]^2 / [HC_2O_4^-]$ $[H^+][A^-]/ [HA]$	**1**

Question Number	Acceptable Answers	Reject	Mark
18 (a) (iii)	No TE on (a)(ii) $K_a = 10^{-4.28}$ OR 5.24807×10^{-5} (mol dm^{-3}) **(1)** $K_a = [H^+]^2 / [HC_2O_4^-]$ $K_a = [H^+]^2 / 0.050$ $[H^+] = \sqrt{(0.05 \times 10^{-4.28})} = 1.61988 \times 10^{-3}$ (mol dm^{-3}) **(1)** TE on incorrect K_a value pH = −log 1.61988×10^{-3} = 2.7905 = 2.8 **(1)** For final mark TE on algebraic / arithmetical errors providing pH ≥ 1.3 Correct answer with no working scores 3 Ignore SF except 1 SF		**3**

Question Number	Acceptable Answers	Reject	Mark
18(b)(i)	IGNORE explanations **First mark:** $HC_2O_4^-$/hydrogenethanedioate ion ionization negligible ALLOW Acid for $HC_2O_4^-$ Slight / partial / incomplete / does not dissociate for negligible OR $[HC_2O_4^-]_{equilibrium} = [HC_2O_4^-]_{initial} / 0.050$ (mol dm^{-3}) **(1)** **Second mark:** $[H^+]$ due to ionization of water negligible OR auto ionization of water negligible OR $[H^+]$ only due to ionization of $HC_2O_4^-$/acid OR $[C_2O_4^{2-}] = [H^+]$ **(1)** IGNORE references to temperature and to HA and A^- Penalize omission of [] in discussion once only	Use of $NaHC_2O_4$ for $HC_2O_4^-$ OR sodium hydrogen-ethanedioate for hydrogen-ethanedioate ion throughout this item	**2**

Question Number	Acceptable Answers	Reject	Mark
18(b)(ii)	Ethanedioic acid is a (much) stronger acid (than hydrogenethanedioate ion / sodium hydrogenethanedioate) OR Ethanedioic acid has a (much) smaller pK_a (than hydrogenethanedioate) OR Ionization / dissociation of ethanedioic acid is (much) greater (than hydrogenethanedioate) OR Reverse arguments **(1)** IGNORE $NaHC_2O_4$ ionization negligible Approximation of negligible ionization invalid / incorrect OR $[H_2C_2O_4]_{equilibrium}$ not equal to $[H_2C_2O_4]_{initial}$ **(1)** No TE on 18(a)(iii) IGNORE Second ionization occurs	Ethanedioic acid is a strong acid / fully dissociated Just 'approximation invalid'	**2**

Question Number	Acceptable Answers	Reject	Mark
18(c)(i)	Start pH at 2.8 ALLOW 2—4 **(1)** Vertical section at 25 cm^3 within pH range 6-11 and 2.5-4 units long **(1)** end pH (approaching) value in range 12-13 (asymptotically) **(1)**	deviation from vertical maximum before final pH	**3**

Question Number	Acceptable Answers	Reject	Mark
18(c)(ii)	**First mark:** Methyl yellow range = 2.9—4 and the phenolphthalein range = 8.2—10 ALLOW pK_{in} (methyl yellow) = 3.5 and pK_{in} (phenolphthalein) = 9.3 **(1)** **Second mark:** (The volumes are different) because ethanedioic acid is dibasic / diprotic / has two **replaceable/acidic** hydrogen atoms ALLOW dicarboxylic (acid) (therefore there are two stages to the neutralization) OR Methyl yellow range coincides with neutralization of first proton and phenolphthalein range coincides with neutralization of second proton **(1)**		**2**

Total for Question 18 = 15 Marks

Question 19: N/A

Section C

Question Number	Acceptable Answers	Reject	Mark
20(a)(i)	(Sodium thiosulfate) (rapidly) reacts with / reduces the iodine (as it is formed) **(1)** So prevents the starch-iodine colour appearing until a fixed amount of reaction has occurred ALLOW (for second mark) So prevents the starch-iodine colour appearing until all the thiosulfate has reacted OR Moles of iodine reacted / thiosulfate ÷ time is (approximately) proportional to the (initial) rate of reaction **(1)** ALLOW Use of 'thio' for thiosulfate	iodide / I^-	**2**

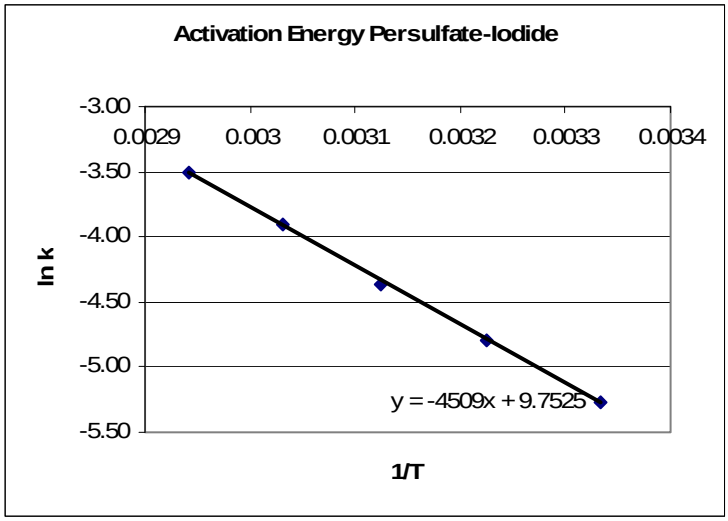
Question Number	Acceptable Answers	Reject	Mark
20(a)(ii)	(From 2 to 1) **$[S_2O_8^{2-}]$** doubles ($[I^-]$ unchanged) and rate doubles / time halves so order wrt **$S_2O_8^{2-}$** = 1 **(1)** (From 3 to 1) **$[I^-]$** doubles ($[S_2O_8^{2-}]$ unchanged) and rate doubles / time halves so order **wrt I^-** = 1 OR (if first mark awarded) (From 3 to 2) **$[I^-]$** doubles ($[S_2O_8^{2-}]$ halved) and rate unchanged so order **wrt I^-** = 1 **(1)** Penalise omission of concentration/square brackets once only Rate = $k[S_2O_8^{2-}][I^-]$ **(1)** Third mark stand alone if no working & TE on incorrect orders IGNORE case of k	Rate equation =	**3**

Question Number	Acceptable Answers	Reject	Mark
20(b)(i)	**First mark** Colorimetry /Use a colorimeter **(1)** **Second mark** Measure transmittance / absorbance (at various times) **(1)** **Third mark** (Use a calibration curve to) convert transmittance / absorbance into concentration. OR transmittance / absorbance proportional to concentration ALLOW Colorimetry may be used because iodine (solution) is coloured (and other reagents are colourless) / to measure intensity of the iodine colour **(1)** ALLOW (for the same three marks) Electrical conductivity Measured at various times / (use a calibration curve to) convert conductivity into concentration. Conductivity reduces as reaction proceeds because 3 mol ions converted to 2 mol ions / fewer ions on right hand side	Sampling methods calorimeter pH meter Just conductivity changes	**3**

Question Number	Acceptable Answers	Reject	Mark
20(b)(ii)	$[(NH_4)_2S_2O_8]$ / $[S_2O_8^{2-}]$ / [peroxodisulfate] / [persulfate] remains (approximately) unchanged during the reaction. OR [KI] / $[I^-]$ is the only variable	$(NH_4)_2S_2O_8$ in excess. $[(NH_4)_2S_2O_8]$ etc does not affect the rate Only [KI] / $[I^-]$ affects the rate	**1**

Question Number	Acceptable Answers	Reject	Mark
20(b)(iii)	Plot a graph of concentration (of iodine/I_2) (on the y axis) against time **(1)** Measure the initial gradient / gradient at t=0 **(1)** 'Plot a graph and measure the initial gradient / gradient at t=0' alone scores second mark		**2**

Question Number	Acceptable Answers	Reject	Mark
20(b)(iv)	TE on 20(a)(ii) on numerical answer and appropriate units $8.75 \times 10^{-5} = k \times 2.0 \times 0.025$ $k = 8.75 \times 10^{-5} / (2.0 \times 0.025)$ $= 1.75 \times 10^{-3}$ **(1)** $dm^3\ mol^{-1}\ s^{-1}$ **(1)** ALLOW units in any order Correct answer including units with no working scores 2	1 SF	**2**

Question Number	Acceptable Answers	Reject	Mark
20(c)(i)	 Use the overlay to mark the graph At least 4 points within the circles on the overlay **(1)** Best fit line on points given **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
20(c)(ii)	Gradient = −(−3.50 − −5.27) / (0.00333 − 0.00294) = (−)4538 = (−)4500 ALLOW values from (−)4300 to (−)4700 **(1)** gradient value negative **(1)** E_a = −gradient x R = −−4538 x 8.31 = (+)37700 J mol^{-1} (= (+)38 kJ mol^{-1}) **(1)** TE on value of gradient even if it is positive −4300 gives 35.7; −4700 gives 39.1 Correct units **(1)** Correct answer from the gradient calculation with units scores final 2 marks **BUT** correct answer with units but no gradient calculation scores units mark only		**4**

Total for Section C = 19 Marks

6 b	C		**1**
21	A		**1**
22 a	A		**1**
b	C		
23	B		**1**
24	D		**1**
25a	D		**1**
b	A		**1**
26a	A		**1**
b	C		**1**
c	D		**1**
d	B		**1**

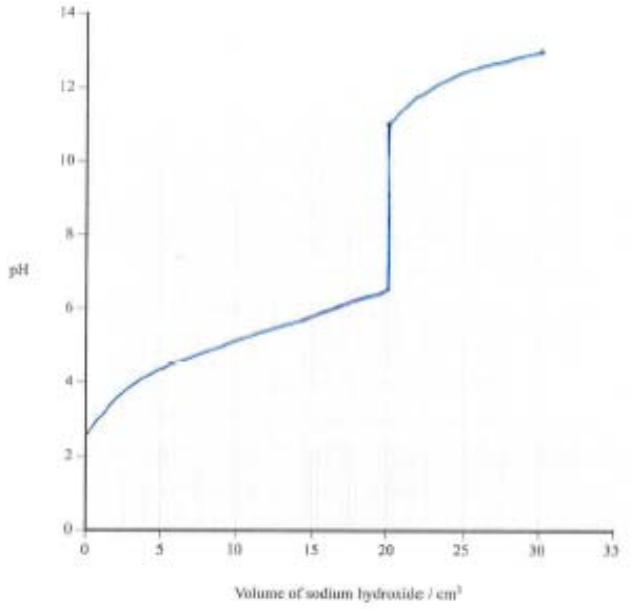
Section B

Question Number	Acceptable Answers	Reject	Mark
27 (a)(i)	*K*a = $[CH_3CO_2^-]$ $[H^+]/[CH_3CO_2H]$ OR *K*a = $[CH_3CO_2^-]$ $[H_3O^+]/[CH_3CO_2H]$ OR Use of $[CH_3COO^-]$ instead of $[CH_3CO_2^-]$ and $[CH_3COOH]$ instead of $[CH_3CO_2H]$ IGNORE state symbols even if wrong	Numerator as $[H^+]^2$ Expressions in terms of HA alone Round/curved brackets '()' Any other carboxylic acid	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	$1.7 \times 10^{-5} = [H^+]^2 / 0.5$ $[H^+] = \sqrt{1.7 \times 10^{-5} \times 0.5} / 2.915(476) \times 10^{-3}$ **(1)** pH = $(-\log[H^+])$ = 2.53529 OR = 2.54 OR = 2.5 **(1)** ALLOW TE for second mark from any hydrogen ion concentration as long as pH less than 7 Correct answer alone scores **(2)** ALLOW pH = 2.53 if $[H^+]$ is rounded to 2.92×10^{-3} IGNORE sf except 1	4.77 or 4.8 from using pH = -log Ka loses both marks	**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	20 (cm^3) IGNORE units OR 0.02 dm^3		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	Moles of excess NaOH = 10/1000 x 0.50 = 5×10^{-3} **(1)** So [NaOH/OH^-] = 5×10^{-3} x 1000/50 = 0.10 mol dm^{-3} **(1)** EITHER Kw route: $[H^+] \times 0.1 = 1 \times 10^{-14}$ **(1)** So pH = - log 1×10^{-14} / 0.1 = 13 **(1)** OR pOH route: pOH = 1 **(1)** So pH = (14 – 1) = 13 **(1)** ALLOW TE throughout Correct final answer scores **(4)**		**4**

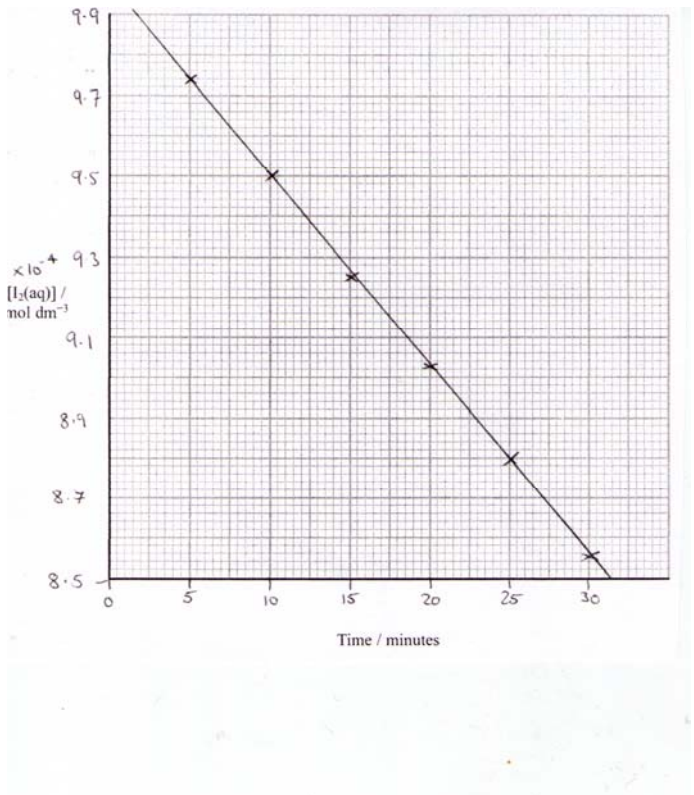
Question Number	Acceptable Answers	Reject	Mark
(a)(v)	Starting at pH 2-3 AND finishing at pH between 12 and 13.7 inclusive **(1)** Vertical section at 20 cm^3 **(1)** S-shaped curve, with gradual rise and vertical section within the pH range 5.5 and 11.5 and of 3 to 5 units in length **(1)** These are stand alone marks  		**3**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	EITHER [base] = Ka [acid]/[H^+] Or [H+] = ($10^{-pH4.70}$) = 1.995 x 10^{-5} **(1)** [base] = 1.7 x 10^{-5} x 1/(1.995 x 10^{-5}) = 0.852 **(1)** moles base = 0.852 x 0.5 = 0.426 (mol) **(1)** mass base = 0.426 x 82 = 34.9 g **(1)** IGNORE sf except 1 Correct answer, with or without working **(4)** OR pH = p*K*a – log[acid]/[base] 4.70 = 4.8 – log [1/[base]] Log[1/[base]] = 0.1 **(1)** [base] = 0.794(328) (mol dm^{-3}) **(1)** So in 500 cm^3 Moles = 0.794 x 0.5 = 0.397 mol **(1)** Mass = 0.397 x 82 = 32.554/32.6 g **(1)** (ALLOW using p*K*a = 4.77)		**4**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	**First mark** Buffer has large amount/ excess/ reservoir of CH_3COOH (and CH_3COO^-) **(1)** **Second mark** OH^- ions added react with CH_3COOH OR $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$ OR $OH^- + H^+ \rightarrow H_2O$ **and** $CH_3COOH \rightarrow CH_3COO^- + H^+$ OR Equations described in words **(1)** **Third mark** Ratio / values of $[CH_3COOH]$ to $[CH_3COO^-]$ remains (almost) unchanged **(1)** IGNORE concentration of hydrogen ions remains constant ALLOW answers in terms of HA and A^-		**3**

Question Number	Correct Answer	Reject	Mark
28 (a)(i)	Sodium thiosulfate/$Na_2S_2O_3$ ALLOW $S_2O_3^{2-}$ or thiosulfate ions	Just thiosulfate	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Add (excess) sodium hydrogencarbonate/ $NaHCO_3$ **(1)** To neutralize/remove/react with acid (catalyst) **(1)** Cool in ice (water) with no reference to neutralization – allow 1 mark but ignore if either of first two marks awarded	NaOH/ sodium hydroxide/ alkali just cold water	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	Suitable graph and scale **(1)** Points plotted and line of best fit **(1)** 0 order (with respect to iodine) **(1)**  		**3**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Graph is a straight line/Gradient is constant **(1)** Rate stays constant (as iodine used up)/ Concentration has no effect on rate **(1)** Stand alone marks	Half life is constant	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)	Colorimetry/use of pH meter/conductivity/titrate with $AgNO_3$/titrate with alkali (to monitor change in $[H^+]$)	C**a**lorimetry Use of starch/ Iodine clock reaction	**1**

Question Number	Correct Answer	Reject	Mark
29(a)	**First mark** Enthalpy change when 1 mol of **gaseous** ions **(1)** ALLOW energy change/heat change/energy evolved/released/ given out/exothermic **Second mark** Is dissolved/hydrated/solvated such that further dilution causes no further heat change OR Is dissolved to produce an infinitely dilute solution/in excess water **(1)** ALLOW Is dissolved to produce a solution of 1.0 mol dm^{-3}	Energy required or energy taken in Atoms or molecules (0) 1 mol of water	**2**

Question Number	Acceptable Answers	Reject	Mark
29(b)(i)	$K^+(aq)$ (+) $F^-(aq)$	$K^+ F^-(aq)$	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	$\Delta H_{sol} = -\Delta H_1 + \Delta H_2$ OR $\Delta H_{sol} = \Delta H_2 - \Delta H_1$		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	(Standard) Lattice(enthalpy/energy/$\triangle$H)	LE/Lat **-** Lattice	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	**First mark** Selection of (-)817 rather than (-)807 **(1)** **Second mark** ΔH_{sol} = 817 – 805 = (+)12 (kJ mol^{-1}) **(1)** Just (+)12 (kJ mol^{-1}) **(2)** ALLOW TE for second mark e.g. for 807 gives (+) 2 (kJ mol^{-1}) ALLOW TE from incorrect b(ii)	-12 (max 1)	**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	EITHER No change/no measurable change in temperature OR (Very small) decrease in temperature **(1)** Thermometer not sensitive/precise enough/precision of thermometer is + or - 0.5 ^{o}C/graduations too large **(1)** Amount of energy taken in is small /ΔH_{sol} is small/mass of sodium chloride is small/slightly endothermic **(1)**	Any reference to temp increase /exothermic Just accuracy +/- 1 ^{o}C	**3**

Question Number	Acceptable Answers	Reject	Mark
***29(c)(ii)**	(The reaction is endothermic so) Entropy(change) of surroundings decreases OR ΔS_{sur} is negative OR $-\Delta H/T$ is negative **(1)** But entropy (change)of system increases (as there is an increase in disorder) OR ΔS_{sys} is positive **(1)** Increase in entropy of system outweighs/greater than decrease in entropy of surroundings / value for entropy change of system is greater than entropy change of surroundings **(1)** Total entropy (change) is positive **(1)** All marks are stand alone	S_{sur} is negative S_{sys} is positive	**4**

Question Number	Acceptable Answers	Reject	Mark
***29(d)**	Any four from: The difference between Born Haber and theoretical LE is greater for LiI than for LiCl **(1)** (845 and 848 =) 3 for LiCl whereas (738 and 759 =) 21 for LiI **(1)** Iodide ion is larger than chloride ion/lower charge density on iodide ion **(1)** The iodide ion is more likely (than the chloride ion) to be polarized (by lithium ion) **(1)** LiI likely to have more covalent character than LiCl **(1)**	Reject values with + Iodine/Chlorine atoms or molecules Iodine/Chlorine atoms or molecules	**4**