Question Number	Acceptable Answers	Reject	Mark
1 (a)	ΔS_{system} = (3x2x65.3 +197.6) – (186.2 + 188.7) Correct data for CH_4 and CO (186.2 and 197.6) **(1)** = (+) **214.5 / 215** (J $mol^{-1} K^{-1}$) / (+) **0.2145 / 0.215 kJ** ($mol^{-1} K^{-1}$) **(1)** Units must be shown if data has been converted to kJ Full marks (2) for correct answer without working Ignore sf except 1 Answer of -214.5 scores (1) Answer of +18.6 if entropy of H not doubled scores (1) Answer of –46.7 if entropy of H_2 not tripled scores (1) ALLOW TE in second mark for minor error in data e.g. writing 63.5 instead of 65.3. No TE if data used is not entropy of compounds.	**214** **0.214**	**2**

Question Number	Acceptable Answers	Reject	Mark
1 (b)	$(\Delta S_{surroundings}) = \frac{-\Delta H}{T}$ Expression or use of expression, $\frac{-206.1 \times (1000)}{298}$ **(1)** = **-691.6 J** ($mol^{-1} K^{-1}$)/ **-0.6916 kJ** ($mol^{-1} K^{-1}$) **(1)** Ignore sf except 1		**2**

Question Number	Acceptable Answers	Reject	Mark
1 (c)	ΔS_{total} = (214.5+(-691.6)) = **-477.1** (J mol^{-1} K^{-1}) / - **0.4771** (kJ mol^{-1} K^{-1}) **(1)** ALLOW TE for answer to (a) plus answer to (b). If 214.5 is added to -0.69 no TE unless -0.69 is specified to be in joules. Ignore sf except 1 Negative / less than zero (so not spontaneous) / would be positive if spontaneous. **(1)** ALLOW "feasible" for spontaneous. If answer to calculation is positive, accept comment that it would be expected to be negative if not spontaneous	Addition of value in J to specified value in kJ Comments on kinetic stability	**2**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Reject</th><th>Mark</th></tr>
<tr><td>*1 (d) (i)</td><td>$K_p = \frac{(pH_2)^3 x (pCO)}{(pCH_4)(pH_2O)}$ (1)

4 Correct partial pressures (3)
<table>
<tr><td></td><td>CH_4</td><td>H_2O</td><td>CO</td><td>H_2</td></tr>
<tr><td>pp</td><td>0.25</td><td>0.25</td><td>0.375</td><td>1.125</td></tr>
</table>
ALLOW partial pressures as fractions

$K_p = \frac{(1.125)^3 \times (0.375)}{(0.25)(0.25)}$ = 8.54 atm^2

value of K_p (1)

unit (1) (Stand alone mark)

Correct calculation without working scores the 5 calculation marks.

TE from K_p expression if inverted
Ignore sf except 1

If any partial pressures are incorrect:
Calculating total number of moles (6.4) (1)

Calculating mole fractions (0.125, 0.125, 0.1875, 0.5625 if total number of moles is correct) (1)

Multiplying mole fractions by total pressure (x 2 atm) (1)

value of K_p (1)

unit (1) (stand alone mark)

ALLOW TE in value of K_p only from incorrect partial pressures, not using values in question as not using equilibrium moles

If treated as a K_c calculation following K_p expression :
K_p expression (1)
units atm^2 (1)

Max. mark (2)</td><td>Square brackets

TE for K_p expression with addition, not multiplication</td><td>6</td></tr>
</table>

Question Number	Acceptable Answers	Reject	Mark
1 (d) (ii)	ΔS_{total} = (8.31 ln 8.54) = (+)**17.8** (J mol^{-1} K^{-1}) Accept any value that rounds to 17.8 TE from value in (i) K_p value of 87.48 (obtained by treating calculation in (i) as K_c) gives ΔS_{total} = **37.16 / 37.12**		**1**

Question Number	Acceptable Answers	Reject	Mark
1 (d) (iii)	$17.8 = 225 - \frac{206.1 \times 1000}{T}$ **(1)** $T = \frac{206.1 \times 1000}{207.2}$ = **995 / 990** (K) **(1)** Correct answer with no working shown scores 2 Correct method with wrong answer or missing 10^3 scores 1 TE from (ii) K_p value of 87.48 gives T = **1097** **OR** If ΔS_{total} is taken as zero $0 = 225 - \frac{206.1 \times 1000}{T}$ **(1)** T = **916**K **(1)** K_p value of 87.48 gives T = **916** Ignore sf except 1		**2**

Question Number	Acceptable Answers	Reject	Mark
***1 (e)**	$\Delta S_{surroundings}$ / $\frac{-\Delta H}{T}$ becomes less negative making ΔS_{total} more positive (as T increases) **OR** $\Delta S_{surroundings}$ / $\frac{-\Delta H}{T}$ becomes less negative making ΔS_{total} greater (as T increases) **OR** (magnitude of) $\Delta S_{surroundings}$ becomes less / lower making ΔS_{total} more positive / greater (as T increases) **(1)** Because ΔS_{total} increases equilibrium constant increases **(1)** **OR** value of ΔS_{total} at new temperature is more than at 298K (1) (must be clear that the two ΔS_{total} values at the different temperatures have been considered) Because ΔS_{total} increases equilibrium constant increases (1)	Le Chatelier statements without reference to entropy changes Just 'as temperature increases ΔS_{total} increases'	**2**

Question Number	Acceptable Answers	Reject	Mark
2 (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
2 (b)(i)	(+)27.3 **and** (+)87.4 (J mol^{-1} K^{-1}) *IGNORE* incorrect units		**1**

Question Number	Acceptable Answers	Reject	Mark
2 (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
2 (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
2 (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
2 (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**