Mark Scheme

Question	Answer	Marks	Guidance
1	C	**1**	
2	B	**1**	

Mark Scheme

Question			Answer	Marks	AO element	Guidance
3	(a)		High pressure **AND** low temperature ✓ Right-hand side has fewer (gaseous) moles/molecules **OR** left-hand side has more (gaseous) moles/molecules ✓ (Forward) reaction is exothermic/gives out heat **OR** reverse reaction is endothermic/takes in heat ✓	**3**	1.2×1 1.1×2	Marks are independent **ORA** throughout **ALLOW** RHS **ALLOW** suitable alternatives for RHS e.g. product side
	(b)		(Reaction can be carried out at) lower temperatures / lower energy demand ✓ Less (fossil) fuels burnt / less CO_2 emissions ✓	**2**	1.1×2	**ALLOW** lower pressures as alternative to lower temperature **ALLOW** reduced carbon footprint as alternative to less fuels burnt **ALLOW** different reactions can be used with greater atom economy / less waste **ALLOW** can reduce use of toxic substances

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(c)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 25.55 kJ mol^{-1} **OR** 25550 J mol^{-1} **award first 4 marks** --- ΔS = 238 – (198 **+** 2 × 131) ✓ = –222 (J K^{-1} mol^{-1}) **OR** –0.222 (kJ K^{-1} mol^{-1}) ✓ $\Delta G = \Delta H - T\Delta S$ **OR** ΔG = –91 – (525 × –0.222) **OR** ΔG = –91000 – (525 × –222) ✓ = 25.55 kJ mol^{-1} **OR** 25550 J mol^{-1} ✓ (Reaction is) not feasible **AND** $\Delta G > 0$ ✓	**5**	2.2×4 3.2×1	**ALLOW ECF** **IGNORE** units at this stage Units for ΔG required **ALLOW** 26 kJ mol^{-1} **OR** 26000 J mol^{-1} up to calculator value.

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Question			Answer	Marks	AO element	Guidance
	(d)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 2.22 $\times$ 10^4 **award first 2 marks** --- ln $K_p = -\Delta G/RT = \frac{2.48 \times 10^4}{8.314 \times 298}$ = 10.01 ✓ K_p = 2.22 $\times$ 10^4 (**3SF required**) ✓ Units = atm^{-2} ✓	**3**	3.1×2 1.2×1	**ALLOW ECF** for transcription errors in first sum **ALLOW** 10 up to calculator value of 10.00979992 **ALLOW** 22200 **ALLOW** 2.20 $\times$ 10^4 **OR** 22000 (use of 10) **ALLOW** alternatives (k)Pa^{-2} **OR** N^{-2} m^4 **OR** $mmHg^{-2}$ **OR** PSI^{-2} **OR** bar^{-2} **Common errors for 1 mark:** 22400 (use of 8.31) 4.50 x 10^{-5} (use of -10.01)
			Total	**14**		

Mark Scheme

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>4</td><td>(a)</td><td></td><td>
<table>
<tr><td>T /K</td><td>500</td><td>600</td><td>700</td><td>800</td></tr>
<tr><td>K_p</td><td>5.86×10^{45}</td><td>1.83×10^{37}</td><td>1.46×10^{31}</td><td>1.14×10^{26}</td></tr>
<tr><td>$\frac{1}{T}$ /K^{-1}</td><td>2.00×10^{-3}</td><td>1.67×10^{-3}</td><td>1.43×10^{-3}</td><td>1.25×10^{-3}</td></tr>
<tr><td>ln K_p</td><td>105</td><td>86</td><td>72</td><td>60</td></tr>
</table>
✓ ✓

Calculator values
1/T /10^{-3} 2.00 1.66 recurring 1.428571429 1.25
ln K_p 105.3844788 85.79996441 71.75857432 59.99824068</td><td>2</td><td>1.2×2</td><td>Mark by row

ALLOW 2 SF or more for 1/T but ignore trailing zeroes

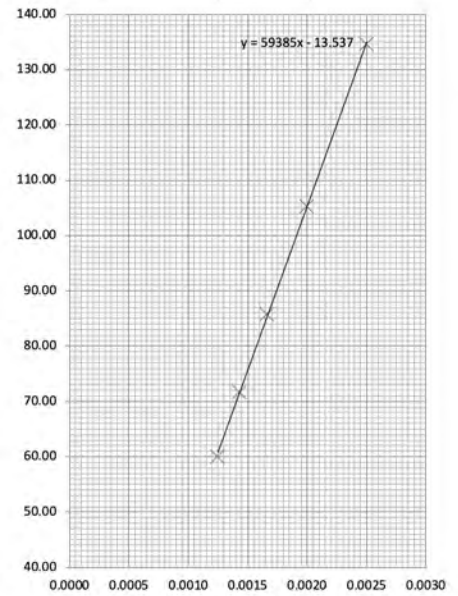
ALLOW whole numbers ~~(±1)~~ for ln K_p

ALLOW 1 small slip in each row.
e.g. 1.66 for 1.67; 71.7 for 71.8
Check with calculator values below table

BUT DO NOT ALLOW whole number errors, e.g. 85 for 86 ☒</td></tr>
<tr><td></td><td>(b)</td><td></td><td>Equilibrium (position) shifts to the left
AND
(forward) reaction is exothermic ✓</td><td>1</td><td>2.2</td><td>ALLOW ‘favours reverse reaction’
Implies shift to left

ALLOW ‘shifts in endothermic direction’ BUT only if (forward) reaction stated as exothermic</td></tr>
</table>

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(c)	**Plotting of graph** **All** points correctly plotted **AND** best-fit straight line ✓	4	3.1	 **ALLOW** 4 points on graph Tolerance 1 small square
	Gradient Correct gradient of best-fit straight line within the range ±57000 → ±63000 ✓		3.1	
	ΔH calculation (subsumes mark for gradient) ΔH = (–) gradient × 8.31(4) **OR** calculated value ✓ *e.g. from ±60000, ΔH = (+)498840* (J) **OR** ±498.840 (kJ)		3.2	
	ΔH in kJ mol^{-1} ΔH correct in kJ mol^{-1} **AND 3SF** **AND** – sign ✓ *e.g. from ±498840, ΔH = –499 (kJ mol^{-1})*		3.2	**ALLOW** ΔH in range: –480 → –530 *(kJ mol^{-1})* **This mark subsumes gradient mark**
(d)	Extrapolate line to (*y*) intercept **OR** Measure/Use (*y*) intercept ✓ Intercept = $\frac{\Delta S}{R}$ **OR** $\Delta S = R \times$ (*y*) intercept ✓ *This statement automatically subsumes 1st mark* **NOTE**: If 'x' intercept, **DO NOT ALLOW** 1st mark but 2nd mark available for × *R* as **BOD**	2	3.1×2	**ALLOW** substitute values of ln K_p, 1/*T* and gradient into **Equation 5.1** ✓ From provided values and gradient = 60000: $\frac{\Delta S}{R}$ = ln K_p – gradient × 1/*T* **OR** 135 – 60000 × 2.50 × 10^{-3} = –15 ✓
	Total	9		