Question	er	Mark	Guidance
1 (a)	process $C_2H_5OH(I) \rightarrow C_2H_5OH(g)$ $\checkmark$ $C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$ $\checkmark$ $V$	2	
(b)	4 correct → 1 mark  ΔH: + AND bonds broken ✓  ΔS: + AND more random/more disorder/more ways of arranging energy ✓	2	Sign and reason required for each mark ALLOW forces of attraction/hydrogen bonds are overcome DO NOT ALLOW response in terms of bonds breaking AND bond making (for melting bonds are just broken) DO NOT ALLOW responses implying that bonds within $H_2O$ molecules are broken IGNORE comments related to $\Delta G$
(c) (i)	$\Delta S = (3 \times 131 + 198) - (186 + 189) \checkmark$ $\Delta S = (+)216 (J K^{-1} mol^{-1}) \checkmark$	2	ALLOW 1 mark for –216 (wrong sign) ALLOW 1 mark for –46 (131 instead of 3 x 131) ALLOW 1 mark for 594 (sign of 189)

Question	er	Mark	Guidance
(c)	Two from points below:  1. fuel <b>OR</b> fuel cells  2. manufacture of margarine <b>OR</b> hydrogenation of alkenes/unsaturated fats  3. manufacture of ammonia <b>OR</b> 'Haber process' ✓  4. manufacture of HCI/hydrochloric acid  5. reduction of metal ores/metal oxides	1	2 uses for one mark  IGNORE hydrogenation of margarine
(d)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = -109, award first 3 marks for calculation		IF there is an alternative answer, check to see if there is any ECF credit possible using working below
	At 298 K, 91.2 = $176 - T\Delta S \checkmark$		ANNOTATE WITH TICKS AND CROSSES, etc
	$\Delta S = \frac{176 - 91.2}{298} = 0.285 \text{ (kJ K}^{-1} \text{ mol}^{-1})$ OR $\Delta S = \frac{176000 - 91200}{298} = 285 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$ subsumes 1st marking point		<b>ALLOW</b> 0.285 (3 SF) up to calculator value of 0.284563758 <b>ALLOW</b> 285 (3 SF) up to calculator value of 284.563758
	At 1000 K, $\Delta G = 176 - 1000 \times 0.285$ = -109 (kJ mol <sup>-1</sup> ) $\checkmark$		<b>ALLOW</b> –109 up to calculator value correctly rounded, i.e. – 108.6, –108.56, etc
			<b>ALLOW ECF</b> from incorrect $\Delta S$ , <i>ie</i> calculated value of $\Delta G$ from $\Delta G = 176 - 1000$ x calculated value of $\Delta S$
	Reaction <b>does</b> take place (spontaneously) because $\Delta G < 0$ <b>OR</b> $\Delta G$ is -ve $\checkmark$ <b>Note</b> : If no value of $\Delta G$ , this mark <b>cannot</b> be awarded.	4	Answer and reason <b>BOTH</b> needed for mark <b>ALLOW</b> reaction is feasible for 'reaction does take place' <b>Note</b> : If candidate has a + $\Delta G$ value, mark <b>ECF</b> , ie reaction does not take place because $\Delta G > 0$ <b>OR</b> $\Delta G$ is +ve
	Total	11	

Question		Expected answers		Additional guidance
а		$\Delta G = \Delta H - T \Delta S \checkmark$	1	
b		process sign		
		$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$		
		$NaCl(s) + (aq) \longrightarrow NaCl(aq)$		
		$H_2O(I) \longrightarrow H_2O(s)$		
		$Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$		
		$CuSO_4(s) + 5H_2O(l) \longrightarrow CuSO_4 \cdot 5H_2O(s)$		
		All 5 correct → 2 marks ✓ ✓ 4 correct → 1 mark ✓	2	
С		$\Delta S = (4 \times 211 + 6 \times 189) - (4 \times 192 + 5 \times 205) \checkmark$		
		$\Delta S = (+)185 (J K^{-1} mol^{-1}) \checkmark$	2	ALLOW ECF from working line above from a single error
				COMMON ERRORS (+)3 (J K <sup>-1</sup> mol <sup>-1</sup> ) $\checkmark$ (211 + 189) – (192 + 205) – 185 (J <sup>-1</sup> mol <sup>-1</sup> ) $\checkmark$ incorrect sign
d		With increasing temperature $T\Delta S$ is more negative <b>OR</b> $T\Delta S$ decreases		ANNOTATIONS MUST BE USED
		OR magnitude of T∆S increases ✓		DO NOT ALLOW just T∆S increases
		At high temperature $T\Delta S$ is more negative that $\Delta H$		<b>DO NOT ALLOW</b> At high $T$ , ' $-T\Delta S$ is greater (than $\Delta H$ )'
		at high $T$ , $T\Delta S$ outweighs/is more significant than $\Delta H$		APPROACH BASED ON TOTAL ENTROPY:
		OR		With increasing temperature
		At low temperature $\Delta H - T\Delta S < 0$		$\Delta H/T$ is less negative <b>OR</b> $\Delta H/T$ increases
			2	<b>OR</b> $-\Delta H/T$ decreases <b>OR</b> $ \Delta H/T $ decreases
		At high temperature $\Delta H - T\Delta S > 0$		OR magnitude of ∆H/T decreases ✓ ALLOW at high temperatures
				$\Delta S - \Delta H/T < 0$
	a b	a b	a $\Delta G = \Delta H - T\Delta S \checkmark$ bprocesssign $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$ — $NaCl(s) + (aq) \longrightarrow NaCl(aq)$ + $H_2O(l) \longrightarrow H_2O(s)$ — $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$ + $CuSO_4(s) + 5H_2O(l) \longrightarrow CuSO_4 \bullet 5H_2O(s)$ —All 5 correct $\longrightarrow 2$ marks $\checkmark$ 4 correct $\longrightarrow 1$ mark $\checkmark$ c $\Delta S = (4 \times 211 + 6 \times 189) - (4 \times 192 + 5 \times 205) \checkmark$ $\Delta S = (+)185 (J K^{-1} mol^{-1}) \checkmark$ dWith increasing temperature $T\Delta S$ is more negative OR $T\Delta S$ decreasesOR $-T\Delta S$ increases OR $ T\Delta S $ increasesOR magnitude of $T\Delta S$ is more negative that $\Delta H$ ORat high $T$ , $T\Delta S$ outweighs/is more significant than $\Delta H$ ORat high $T$ , $T\Delta S$ outweighs/is more significant than $\Delta H$	a $\Delta G = \Delta H - T\Delta S \checkmark$ 1bprocesssign $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$ — $NaCl(s) + (aq) \longrightarrow NaCl(aq)$ + $H_2O(l) \longrightarrow H_2O(s)$ — $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$ + $CuSO_4(s) + 5H_2O(l) \longrightarrow CuSO_4*5H_2O(s)$ — $All \ 5 \ correct$ $\rightarrow 2 \ marks \checkmark$ $4 \ correct$ $\rightarrow 1 \ mark \checkmark$ $2 \ C$ $\Delta S = (4 \times 211 + 6 \times 189) - (4 \times 192 + 5 \times 205) \checkmark$ $\Delta S = (+)185 \ (J \ K^{-1} \ mol^{-1}) \checkmark$ $2$ $d$ With increasing temperature $T\Delta S$ is more negative $OR \ T\Delta S$ decreases $OR \ -T\Delta S$ increases $OR \  T\Delta S $ increases $OR \ magnitude$ of $T\Delta S$ increases $\checkmark$ At high temperature $T\Delta S$ is more negative that $\Delta H$ $OR$ at high $T$ , $T\Delta S$ outweighs/is more significant than $\Delta H$ $OR$ At low temperature $\Delta H \ -T\Delta S < 0$ $OR$ $2$

Question	Expected answers	Marks	Additional guidance
			OR $\Delta S$ is more negative than $\Delta H/T$ OR $\Delta S$ outweighs/ is more significant than $\Delta H/T$
e	(For feasibility,) $\Delta G < 0$ OR $\Delta G = 0$ OR $0 < \Delta H - T \Delta S$ OR $0 = \Delta H - T \Delta S$ OR $0 = 493 - T \times 543/1000 \checkmark$ $T = \frac{\Delta H}{\Delta S} = 493 \times 1000/543 \checkmark$ $= 908 \text{ K} \checkmark$ Units of temperature are <b>required</b>	3	ALLOW total entropy statement: ΔS(total) = 0 OR ΔS(total) >0  ALLOW 0 = 493 − T × 543 ✓ i.e. This mark focuses on ΔG OR ΔH − TΔS being = 0 and NOT on conversion of ΔS value into kJ K⁻¹ mor⁻¹  Mark temperature given on answer line ALLOW 3 SF up to calculator value 907.9189687 correctly rounded, e.g. 907.9, 907.92  ALLOW temperature in °C: i.e. ALLOW by subtraction of 273: 635, 634.9, 634.91 °C ALLOW by subtraction of 273.15: 635, 634.8, 634.77 °C up to calculator value correctly rounded ALLOW C for °C; °K for K  IF ΔS has not been converted to kJ, DO NOT ALLOW 2nd mark BUT ALLOW calculated answer = 493/543 = 0.91 K (calculator: 0.907918968)  ALLOW 2 marks only for absence of one of the
		Total 10	statements required for 1st marking point

Qu	estion	Answer	Mark	Guidance
3	(a)	A: forms fewer moles/molecules of gas ✓ B: forms gas from a liquid ✓ C: forms liquid from gases ✓ D: forms more moles/molecules of gas ✓	4	Note: Responses must imply the key difference between the sides of the equation  IGNORE comments about C(s)
	(b)	$\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$ = 40 + 214 - 89 = 165 (J K <sup>-1</sup> mol <sup>-1</sup> ) = 0.165 (kJ K <sup>-1</sup> mol <sup>-1</sup> ) $\checkmark$ At 25 °C, $\Delta G = +178 - 298 \times 0.165 \checkmark$ = (+)129 $\checkmark$ units: kJ mol <sup>-1</sup> $\checkmark$ OR (+)129,000 $\checkmark$ units: J mol <sup>-1</sup> $\checkmark$ As $\Delta G > 0$ , reaction is <b>not</b> feasible OR as $\Delta G > 0$ , CaCO <sub>3</sub> is stable $\checkmark$	1	ANNOTATE WITH TICKS AND CROSSES, etc  Mark is for the working line: $40 + 214 - 89 = 165$ UNITS have a separate mark  ALLOW 129 to calculator value of 128.83  DO NOT ALLOW 128 (incorrect rounding)  IF 25 °C used rather than 298 K, credit by ECF, calculated $\Delta G$ = 174 to calculator value of 173.875  ENTROPY APPROACH
		Minimum temperature for feasibility when $0 = \Delta H - T\Delta S$ <b>OR</b> $\Delta H = T\Delta S$ <b>OR</b> $T = \frac{\Delta H}{\Delta S}$ $\checkmark$ $= \frac{178}{0.165} = 1079$ K <b>OR</b> 806 °C $\checkmark$ The units <b>must</b> be with the stated temperature	2	ENTROPY APPROACH
		Тс	otal 11	