Question			er	Mark	Guidance
1	(a)		**process** **increase decrease** $C_2H_5OH(l) \rightarrow C_2H_5OH(g)$ ✓ $C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$ ✓ $NH_4Cl(s) + aq \rightarrow NH_4Cl(aq)$ ✓ $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$ ✓ $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ ✓ **All 5 correct ⟶ 2 marks** **4 correct ⟶ 1 mark**	**2**	
	(b)		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 ΔG **IGNORE** comments related to ΔG
	(c)	**(i)**	$\Delta S = (3 \times 131 + 198) – (186 + 189)$ ✓ $\Delta S = (+)216$ (J K^{-1} mol^{-1}) ✓	**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 **OR** fuel cells 2. manufacture of margarine **OR** hydrogenation of alkenes/unsaturated fats 3. manufacture of ammonia **OR** 'Haber process' ✓ 4. manufacture of HCl/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 --- At 298 K, $91.2 = 176 - T\Delta S$ ✓ ΔS (= $\frac{176 - 91.2}{298}$) = 0.285 (kJ K^{-1} mol^{-1}) **OR** ΔS (= $\frac{176000 - 91200}{298}$) = 285 (J K^{-1} mol^{-1}) ✓ *subsumes 1st marking point* At 1000 K, $\Delta G = 176 - 1000 \times 0.285$ = –109 (kJ mol^{-1}) ✓ Reaction **does** take place (spontaneously) because $\Delta G < 0$ **OR** ΔG is -ve ✓ **Note**: If no value of ΔG, this mark **cannot** be awarded.	**4**	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** 0.285 (3 SF) up to calculator value of 0.284563758 **ALLOW** 285 (3 SF) up to calculator value of 284.563758 **ALLOW** –109 up to calculator value correctly rounded, i.e. –108.6, –108.56, etc **ALLOW ECF** from incorrect ΔS, *ie* calculated value of ΔG from ΔG = 176 – 1000 x calculated value of ΔS Answer and reason **BOTH** needed for mark **ALLOW** reaction is feasible for 'reaction does take place' **Note**: If candidate has a + ΔG value, mark **ECF**, ie reaction does not take place because $\Delta G > 0$ **OR** ΔG is +ve
			Total	**11**	

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

Question			Expected answers	Marks	Additional guidance
					OR ΔS is more negative than $\Delta H/T$ **OR** ΔS 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 x 543/1000 ✓ $T = \frac{\Delta H}{\Delta S}$ = 493 x 1000/543 ✓ = 908 K ✓ Units of temperature are **required**	**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*** $\Delta H - T\Delta S$ *being = 0 and* ***NOT*** *on conversion of* ΔS *value into kJ* K^{-1} *mol*$^{-1}$ **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 ºC: i.e. **ALLOW** by subtraction of 273: 635, 634.9, 634.91 ^{o}C **ALLOW** by subtraction of 273.15: 635, 634.8, 634.77 ^{o}C up to calculator value correctly rounded **ALLOW** C for ºC; ºK 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 statements required for 1st marking point***
			Total	**10**	

Question			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)		$\Delta S = \Sigma S$(products) – ΣS(reactants) = 40 + 214 – 89 = 165 (J K^{-1} mol^{-1}) **=** 0.165 (kJ K^{-1} mol^{-1}) ✓ At 25 ˚C, ΔG = +178 – 298 × 0.165 ✓ = (+)129 ✓ units: kJ mol^{-1} ✓ **OR** (+)129,000 ✓ units: J mol^{-1} ✓ As $\Delta G > 0$, reaction is **not** feasible **OR** as $\Delta G > 0$, $CaCO_3$ is stable ✓ ---------- Minimum temperature for feasibility when $0 = \Delta H - T\Delta S$ **OR** $\Delta H = T\Delta S$ **OR** $T = \frac{\Delta H}{\Delta S}$ ✓ $= \frac{178}{0.165}$ = 1079 K **OR** 806 °C ✓ The units **must** be with the stated temperature	1 4 2	**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 ºC used rather than 298 K, credit by **ECF**, calculated ΔG = 174 to calculator value of 173.875 ***ENTROPY APPROACH***---------- **ALLOW** At 25 ˚C, $\Delta S_{total} = 0.165 - \frac{178}{298}$ ✓ = –0.432 ✓ kJ K^{-1} mol^{-1} ✓ **OR** –432 ✓ J K^{-1} mol^{-1} ✓ As $\Delta S < 0$, reaction is **not** feasible ✓ ***ENTROPY APPROACH***---------- Minimum temperature for feasibility when $0 = \Delta S_{system} + \Delta S_{surroundings}$ **OR** $\Delta S_{system} = \frac{\Delta H}{T}$ **ALLOW** 1080 K up to calculator value of 1078.787879, correctly rounded, eg 1078.79 is correct value to 6SF **DO NOT ALLOW** 1078 (incorrect rounding) **IF** 1079 K is given and additional temperature in ºC is incorrect, **IGNORE** ºC temperature (and vice versa)
			Total	**11**	