Detailed Solutions
Gibbs Free Energy — DPP–4 (Numerical)

Q1. **Standard enthalpy & entropy for oxidation of NH_3 at 298 K are -382.64 kJ mol^{-1} and -145.6 J mol^{-1} K^{-1}. Find ΔG° at 298 K.**

(1) **Incorrect** Compute $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = -382.64 - 298(-0.1456) \approx -339.3$ kJ.

(2) **Correct** -339.3 kJ matches the calculation.

(3) **Incorrect** Too large in magnitude.

(4) **Incorrect** Way off.

Final Answer: (2) -339.3 kJ mol^{-1}

Q2. **At 27°C (300 K), $\Delta G = -26$ kcal, $\Delta S = -60$ cal K^{-1}. Find ΔH.**

(1) **Correct** $\Delta H = \Delta G + T\Delta S = -26 + 300(-0.06) = -44$ kcal.

(2) **Incorrect** Uses wrong sign.

(3) **Incorrect** Wrong sign and value.

(4) **Incorrect** Arithmetic error.

Final Answer: (1) -44 kcal

Q3. **At 25°C (298 K), $\Delta H = -11.7\times10^3$ J mol^{-1}, $\Delta S = -105$ J mol^{-1} K^{-1}. Nature of reaction?**

(1) **Incorrect** $\Delta G = -11.7 - 298(-0.105) \approx +19.6$ kJ > 0.

(2) **Correct** $\Delta G > 0$ hence non–spontaneous.

(3) **Incorrect** Would require $\Delta G = 0$.

(4) **Incorrect** We *can* say from given data.

Final Answer: (2) Non–spontaneous

Q4. **$\Delta H = -2.5 \times 10^3$ cal, $\Delta S = 7.4$ cal K^{-1} at 298 K. Predict nature.**

(1) **Correct** $\Delta G = -2500 - 298 \cdot 7.4 \approx -4705$ cal < 0.

(2) **Incorrect** Reversible means $\Delta G = 0$.

(3) **Incorrect** "Irreversible" isn't the spontaneity label; sign says spontaneous.

(4) **Incorrect** Not supported.

Final Answer: (1) Spontaneous

Q5. **At 400 K which is spontaneous *and* endothermic?**

(1) **Incorrect** $\Delta H < 0$ (exo).

(2) **Incorrect** $\Delta H < 0$ (exo) and $\Delta S < 0$.

(3) **Correct** Endothermic $\Delta H > 0$ and $\Delta S > 0 \Rightarrow \Delta G = \Delta H - T\Delta S < 0$ at high T.

(4) **Incorrect** $\Delta H > 0$ but $\Delta S < 0 \Rightarrow$ never spontaneous.

Final Answer: (3)

Q6. **$Ag_2O(s) \rightarrow 2Ag(s) + \frac{1}{2}O_2(g)$ is at equilibrium when $\Delta G^\circ = 0$. Given $\Delta H = 30.56$ kJ mol^{-1}, $\Delta S = 0.066$ kJ K^{-1} mol^{-1}. Find T.**

(1) **Correct** $T = \Delta H/\Delta S = 30.56/0.066 \approx 463$ K ≈ 462.1 K.

(2) **Incorrect**

(3) **Incorrect**

(4) **Incorrect**

Final Answer: (1) ≈ 462.1 K

Q7. **Same reaction with $\Delta H = 30.56$ kJ mol^{-1}, $\Delta S = 66$ J K^{-1} mol^{-1}. T for $\Delta G^\circ = 0$?**

(1) **Incorrect**

(2) **Incorrect**

(3) **Correct** $T = 30.56/0.066 \approx 463$ K.

(4) **Incorrect**

Final Answer: (3) 463 K

Q8. **$\frac{1}{2}A_2 + \frac{1}{2}B_2 \rightarrow AB_2$, $\Delta H = -20$ kJ; $S^\circ(A_2, B_2, AB_2) = (60, 40, 50)$ J K^{-1} mol^{-1}. Temperature for equilibrium?**

(1) **Incorrect**

(2) **Incorrect**

(3) **Incorrect**

(4) **Incorrect**

Final Answer: **Note:** $\Delta S = 50 - (0.5 \cdot 60 + 0.5 \cdot 40) = 0$, so $\Delta G^\circ = \Delta H^\circ = -20$ kJ (independent of T). No finite T makes $\Delta G^\circ = 0$. The question data are inconsistent with the options.

Q9. **1 mol water at 100°C, 1 atm $\rightarrow$ steam at same T, P. ΔG?**

(1) **Incorrect** Latent heat value, not ΔG.

(2) **Incorrect**

(3) **Incorrect**

(4) **Correct** Phase equilibrium at 100°C $\Rightarrow \Delta G = 0$.

Final Answer: (4) 0

Q10. **$Br_2(l) + Cl_2(g) \rightarrow 2BrCl(g)$; $\Delta H = 30$ kJ, $\Delta S = 105$ J K^{-1}. T for equilibrium?**

(1) **Correct** $T = \Delta H/\Delta S = 30/0.105 \approx 285.7$ K.

(2) **Incorrect**

(3) **Incorrect**

(4) **Incorrect**

Final Answer: (1) 285.7 K

Q11. **Vaporization of water at 1 atm: $\Delta H = 40.63$ kJ mol^{-1}, $\Delta S = 108.8$ J K^{-1} mol^{-1}. T for $\Delta G = 0$?**

(1) **Incorrect**

(2) **Correct** $T = 40.63/0.1088 \approx 373.4$ K.

(3) **Incorrect**

(4) **Incorrect**

Final Answer: (2) 373.4 K

Q12. **$\frac{1}{2}\mathrm{X}_2 + \frac{3}{2}\mathrm{Y}_2 \rightleftharpoons \mathrm{XY}_3$, $S^\circ(X_2, Y_2, XY_3) = (60, 40, 50)$ J K^{-1} mol^{-1}, $\Delta H = -30$ kJ. T for equilibrium?**

(1) **Incorrect**

(2) **Incorrect**

(3) **Correct** $\Delta S = 50 - (0.5 \cdot 60 + 1.5 \cdot 40) = -40$ J K^{-1}, $T = \frac{\Delta H}{\Delta S} = (-30)/(-0.04) = 750$ K.

(4) **Incorrect**

Final Answer: (3) 750 K

Q13. **$\Delta H = 35.5$ kJ, $\Delta S = 83.6$ J K^{-1}. When spontaneous?**

(1) **Correct** Threshold $T > \Delta H/\Delta S = 35.5/0.0836 \approx 425$ K.

(2) **Incorrect**

(3) **Incorrect**

(4) **Incorrect**

Final Answer: (1) $T > 425$ K

Q14. **$\mathrm{C(graphite)} + \mathrm{CO_2(g)} \rightarrow \mathrm{2CO(g)}$; $\Delta H = 170$ kJ, $\Delta S = 170$ J K^{-1}. Spontaneous at:**

(1) **Incorrect**

(2) **Incorrect**

(3) **Incorrect** Needs $T > 1000$ K.

(4) **Correct** $T > 1000$ K, so 1110 K works.

Final Answer: (4) 1110 K

Q15. **$\mathrm{CaCO_3(s)} \rightarrow \mathrm{CaO(s)} + \mathrm{CO_2(g)}$; $\Delta H^\circ = +179.1$ kJ, $\Delta S^\circ = 160.2$ J K^{-1} at 298 K. Above which T is it spontaneous (assume const. $\Delta H, \Delta S$)?**

(1) **Incorrect**

(2) **Incorrect**

(3) **Incorrect**

(4) **Correct** $T > \Delta H/\Delta S = 179.1/0.1602 \approx 1118$ K.

Final Answer: (4) 1118 K

Q16. **$X_2O_4(l) \rightarrow 2XO_2(g)$; $\Delta U = 2.1$ kcal, $\Delta S = 20$ cal K^{-1} at 300 K. Find ΔG.**

(1) **Incorrect**

(2) **Correct** $\Delta n_g = 2$, $\Delta H = \Delta U + \Delta n_g RT \approx 2.1 + 2(0.001987 \cdot 300) \approx 3.29$ kcal; $\Delta G = \Delta H - T\Delta S \approx 3.29 - 300(0.02) \approx -2.7$ kcal.

(3) **Incorrect**

(4) **Incorrect**

Final Answer: (2) ≈ -2.7 kcal

Q17. **$2A(g) + B(g) \rightarrow 2C(g)$ at 298 K: $\Delta U^\circ = -10$ kJ, $\Delta S^\circ = -45$ J K^{-1} mol^{-1}. Find ΔG°.**

(1) **Correct** $\Delta n_g = 2 - (2 + 1) = -1$, $\Delta H^\circ = \Delta U^\circ + \Delta n_g RT \approx -10 - 2.48 = -12.48$ kJ; $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \approx -12.48 - 298(-0.045) \approx +0.93$ kJ $\approx +930$ J.

(2) **Incorrect**

(3) **Incorrect**

(4) **Incorrect**

Final Answer: (1) $\approx +930$ J mol^{-1}

Q18. **$\Delta S_{\text{total}} = -40$ kJ K^{-1} mol^{-1}, $\Delta H_{\text{sys}} = 2000$ kJ mol^{-1}, $T = 400$ K. Find ΔS_{system}.**

(1) **Correct** $\Delta S_{\text{surr}} = -\Delta H_{\text{sys}}/T = -2000/400 = -5$ kJ K^{-1}; so $\Delta S_{\text{sys}} = \Delta S_{\text{total}} - \Delta S_{\text{surr}} = -40 - (-5) = -35$.

(2) **Incorrect**

(3) **Incorrect**

(4) **Incorrect**

Final Answer: (1) -35 kJ K^{-1} mol^{-1}

Q19. **$\Delta H = -x$ cal mol^{-1} at 298 K and reaction is spontaneous. About ΔS at 298 K:**

(1) **Incorrect** Would make $\Delta S < -x/298$, giving $\Delta G > 0$.

(2) **Correct** Can be negative but must satisfy $\Delta S > -x/298$ (i.e., numerically smaller than $x/298$).

(3) **Incorrect** It *can* be negative if small in magnitude.

(4) **Incorrect** It can also be positive.

Final Answer: (2)