Chapter 18 Multiple Choice Review Solutions

5. $\Delta S^\circ = \left[S^\circ_{H_2SO_4(l)}\right] - \left[S^\circ_{SO_3(g)} + S^\circ_{H_2O(l)}\right] = \left[156.9 \text{ J/mol}\cdot\text{K}\right] - \left[\left[256.2 \text{ J/mol}\cdot\text{K} + 69.9 \text{ J/mol}\cdot\text{K}\right]\right.$

$= 156.9 \text{ J/mol}\cdot\text{K} - 326.1 \text{ J/mol}\cdot\text{K} = \boxed{-169.2 \text{ J/mol}\cdot\text{K}}$

6. $\Delta G^\circ = 0 = \Delta H_{vap} - T\,\Delta S_{vap} = (21.16 \text{ kJ/mol})(1000 \text{ J/kJ}) - (-35.4^\circ\text{C} + 273)\,\Delta S_{vap}$

$\Delta S_{vap} = \dfrac{2.116 \times 10^4 \text{ J/mol}}{238 \text{ K}} = \boxed{88.9 \text{ J/mol}\cdot\text{K}}$

9. $\Delta S^\circ = \left[2\,\Delta G^\circ_{HNO_3(l)} + \Delta G^\circ_{NO(g)}\right] - \left[3\Delta G^\circ_{NO_2(g)} + \Delta G^\circ_{H_2O(l)}\right]$

$= \left[2(-79.9 \text{ kJ/mol}) + (86.7 \text{ kJ/mol})\right] - \left[3(51.8 \text{ kJ/mol}) + (-237.2 \text{ kJ/mol})\right]$

$= -73.1 \text{ kJ/mol} - (-81.8 \text{ kJ/mol}) = \boxed{+8.7 \text{ kJ/mol}}$

10. $\Delta G^\circ = \Delta H^\circ - T\,\Delta S^\circ = -199 \text{ kJ/mol} - (298 \text{ K})(-4.1 \text{ J/mol}\cdot\text{K})(1 \text{ kJ/1000 J})$

$= -199 \text{ kJ/mol} + 1.2 \text{ kJ/mol} = \boxed{-198 \text{ kJ/mol}}$

11. $\Delta G^\circ = \Delta H^\circ - T\,\Delta S^\circ = (128.9 \text{ kJ/mol}) - (298 \text{ K})\,\Delta S^\circ = 33.1 \text{ kJ/mol};$

$\Delta S^\circ = -\dfrac{33.1 \text{ kJ/mol} - 128.9 \text{ kJ/mol}}{298 \text{ K}} = 0.321 \text{ kJ/mol}\cdot\text{K}$

$\Delta G^\circ = 0 = \Delta H^\circ - T\,\Delta S^\circ = (128.9 \text{ kJ/mol}) - (T)(0.321 \text{ kJ/mol}\cdot\text{K})$

$T = \dfrac{128.9 \text{ kJ/mol}}{0.321 \text{ kJ/mol}\cdot\text{K}} = \boxed{402 \text{ K}}$

13. $\Delta G^\circ = \Delta H^\circ - T\,\Delta S^\circ = (-98.2 \text{ kJ/mol}) - (298 \text{ K})(70.1 \text{ J/mol}\cdot\text{K})(1 \text{ kJ/1000 J})$

$= -119 \text{ kJ/mol}$

$K_p = e^{-\frac{\Delta G^\circ}{RT}} = e^{-\frac{(-119 \text{ kJ/mol})(1000 \text{ J/1 kJ})}{(8.314 \text{ J/mol·K})(298 \text{ K})}} = \boxed{7.2 \times 10^{20}}$

14. $\Delta G^\circ = -\text{RT } \ln K_P = -(8.314 \text{ J/mol}\cdot\text{K})(1 \text{ kJ/1000 J})(1500 + 273)\ln(1.4 \times 10^{-7})$

$= -(14.7)(-15.8) = \boxed{233 \text{ kJ/mol}}$

15. $\Delta G^\circ = -\text{RT } \ln K_P = -(8.314 \text{ J/mol}\cdot\text{K})(1 \text{ kJ/1000 J})(298 \text{ K})\ln(7.7 \times 10^{-13})$

$= 69.1 \text{ kJ/mol}$

$\Delta G = \Delta G^\circ + \text{RT}\ln Q = \Delta G^\circ + \text{RT}\ln\left([Ag^+][Br^-]\right)$

$= 69.1 \text{ kJ/mol} + (8.314 \text{ J/mol}\cdot\text{K})(1 \text{ kJ/1000 J})(298 \text{ K})\ln\left(1.0 \times 10^{-2} \times 1.0 \times 10^{-3}\right)$

$= 69.1 \text{ kJ/mol} + (2.48 \text{ kJ/mol})(-11.51) = \boxed{40.6 \text{ kJ/mol}}$

18. $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$

$\Delta G° = 2\Delta G_f^o(NO_2) - \Delta G_f^o(N_2O_4) = 2(51.8\ \text{kJ/mol}) - (98.29\ \text{kJ/mol}) = 5.3\ \text{kJ/mol}$

$\Delta H° = 2\Delta H_f^o(NO_2) - \Delta H_f^o(N_2O_4) = 2(33.85\ \text{kJ/mol}) - (9.66\ \text{kJ/mol}) = 58.04\ \text{kJ/mol}$

$\Delta G° = \Delta H° - T\Delta S°;\ T = 25°C + 273 = 298K$, so $5.3\ \text{kJ/mol} = 58.04\ \text{kJ/mol} - (298K)\Delta S°$

$$\Delta S° = \frac{58.04\ \text{kJ/mol} - 5.3\ \text{kJ/mol}}{298\ \text{K}} = 0.177\ \text{kJ/mol}\cdot\text{K}$$

At eq. $\Delta G° = 0 = 58.04\ \text{kJ/mol} - T(0.177\ \text{kJ/mol}\cdot\text{K})$

$$\text{So } T = \frac{58.04\ \text{kJ/mol}}{0.177\ \text{kJ/mol}\cdot\text{K}} = 328\ \text{K};\ T = 328\ \text{K} - 273\ = 55°C$$

19. $C_6H_{15}B(l) \rightleftharpoons C_6H_{15}B(g)$

$\Delta G° = \Delta G_f^o[C_6H_{15}B(g)] - \Delta G_f^o[C_6H_{15}B(l)] = (16.1\ \text{kJ/mol}) - (9.4\ \text{kJ/mol}) = 6.7\ \text{kJ/mol}$

$\Delta H° = \Delta H_f^o[C_6H_{15}B(g)] - \Delta H_f^o[C_6H_{15}B(l)] = (-157.7\ \text{kJ/mol}) - (-194.6\ \text{kJ/mol}) = 36.9\ \text{kJ/mol}$

$\Delta G° = \Delta H° - T\Delta S°;\ T = 25°C + 273 = 298K$, so $6.7\ \text{kJ/mol} = 36.9\ \text{kJ/mol} - (298K)\Delta S°$

$$\Delta S° = \frac{36.9\ \text{kJ/mol} - 6.7\ \text{kJ/mol}}{298\ \text{K}} = 0.101\ \text{kJ/mol}\cdot\text{K}$$

At eq. $\Delta G° = 0 = 36.9\ \text{kJ/mol} - T(0.101\ \text{kJ/mol}\cdot\text{K})$

$$\text{So } T = \frac{36.9\ \text{kJ/mol}}{0.101\ \text{kJ/mol}\cdot\text{K}} = 365\ \text{K};\ T = 365\ \text{K} - 273\ = 92°C$$

20. $C_{10}H_8(s) \rightleftharpoons C_{10}H_8(g)$

$\Delta G° = \Delta G_f^o[C_{10}H_8(g)] - \Delta G_f^o[C_{10}H_8(s)] = (224.1\ \text{kJ/mol}) - (201.6\ \text{kJ/mol}) = 22.5\ \text{kJ/mol}$

$\Delta H° = \Delta H_f^o[C_{10}H_8(g)] - \Delta H_f^o[C_{10}H_8(s)] = (150.6\ \text{kJ/mol}) - (78.5\ \text{kJ/mol}) = 72.1\ \text{kJ/mol}$

$\Delta G° = \Delta H° - T\Delta S°;\ T = 25°C + 273 = 298K$, so $22.5\ \text{kJ/mol} = 72.1\ \text{kJ/mol} - (298K)\Delta S°$

$$\Delta S° = \frac{72.1\ \text{kJ/mol} - 22.5\ \text{kJ/mol}}{298\ \text{K}} = 0.166\ \text{kJ/mol}\cdot\text{K}$$

$\Delta G° = \Delta H° - T\Delta S°;\ T = 35°C + 273 = 308K,$

$\Delta G° = 72.1\ \text{kJ/mol} - (308\ \text{K})(0.166\ \text{kJ/mol}\cdot\text{K}) = 21.0\ \text{kJ/mol}$

$\Delta G° = -RT\ln K$

So $21.0\ \text{kJ/mol} = -(8.31\ \text{J/mol}\cdot\text{K})(1\ \text{kJ}/1000\ \text{J})(308K)\ln K$

$$\ln K = \frac{-21.0}{(8.31)(1/1000)(308)} = -8.19;\ K = e^{-8.19} = 2.8\times10^{-4}$$

$K = P_{C_{10}H_8} = 2.8\times10^{-4}\ \text{atm}\ \times\ 760\ \text{mm Hg/atm} = 0.21\ \text{mm Hg}$