CH 223 – Worksheet 6

1. The normal boiling point of ethanol (C_2H_5OH) is 78.3 °C, and its molar enthalpy of vaporization is 38.56 kJ/mol. What is the change in entropy in the system when 68.3 g of C_2H_5OH (g) at 1 atm condenses to a liquid at the normal boiling point?

$$68.3g\ C_2H_5OH\left(\frac{1\ mol}{46g}\right) = 1.485\ mol\ C_2H_5OH$$

$$\Delta S = \frac{-\Delta H}{T} = \frac{(1.485\ mol\ C_2H_5OH)(38.56\ \frac{kJ}{mol})}{351\ K}$$

$$= 0.163\ \frac{kJ}{K} = 163\ \frac{J}{K}$$

2. The normal freezing point of 1-propanol (C_3H_8O) is –127 °C. (a) Is the freezing an endothermic or exothermic process? (b) In what temperature range is the freezing of 1-propanol a spontaneous process? (c) In what temperature range is it a nonspontaneous process? (d) Is there any temperature at which liquid and solid 1-propanol are in equilibrium? Explain.

a) exothermic

b) $< -127°C$

c) $> -127°C$

d) equilibrium occurs at $-127°C$ and 1 atm.

3. Using data from Appendix C, calculate ΔH°, ΔS°, and ΔG° at 25 °C for the following reaction:

Show that ΔG° = ΔH° - TΔS°

$BaCO_3$ (s) →	BaO (s) +	CO_2 (g)	
kJ/mol	kJ/mol	J/mol·K	
-1216.3	-553.5	-393.5	ΔH
-1137.6	-525.1	-394.4	ΔG
112.1	70.42	213.6	ΔS

$$\Delta H = \sum n\,\Delta H°(products) - \sum m\,\Delta H°(reactants)$$

$$\Delta H = \left[-553.5\frac{kJ}{mol} + -393.5\frac{kJ}{mol}\right] - \left[-1216.3\frac{kJ}{mol}\right] = 269.3\,kJ$$

$$\Delta S = \sum n\,S°(products) - \sum m\,S°(reactants)$$

$$\Delta S = \left[70.42\frac{J}{mol\cdot K} + 213.6\frac{J}{mol\cdot K}\right] - \left[112.1\frac{J}{mol\cdot K}\right] = 171.32\frac{J}{K}$$

$$\Delta G = \Delta H - T\Delta S = 269.3\,kJ - 298K\left(0.17132\frac{kJ}{K}\right) = \boxed{218.2\,kJ}$$

$$\text{or } \Delta G = \sum n\,\Delta G°(products) - \sum m\,\Delta G°(reactants)$$

$$\Delta G° = \left[-525.1\frac{kJ}{mol} + -394.4\frac{kJ}{mol}\right] - \left[-1137.6\frac{kJ}{mol}\right] = \boxed{218.2\,kJ}$$

They are the same.

4. Use data from Appendix C to calculate the equilibrium constant, K, at 298 K for the following reaction:

$$C_2H_5OH\,(g) \rightleftharpoons C_2H_4\,(g) + H_2O\,(g)$$

$$-168.5\ \frac{kJ}{mol} \quad 68.11\ \frac{kJ}{mol} \quad -228.57\ \frac{kJ}{mol}$$

$$\Delta G = \Delta G^\circ + Rt \ln Q$$

$$\Delta G^\circ = \sum n\, \Delta G^\circ(\text{products}) - \sum m\, \Delta G^\circ(\text{reactants})$$

$$= \left[68.11\ \frac{kJ}{mol} + -228.57\ \frac{kJ}{mol}\right] - \left[-168.5\ \frac{kJ}{mol}\right]$$

$$= 8.04\ \frac{kJ}{mol}$$

at equilibrium

$$\Delta G = 0 = \Delta G^\circ + RT \ln K \quad \text{at eq. } K = Q$$

$$\therefore \quad \Delta G^\circ = -RT \ln K \qquad R = 8.314\ \frac{J}{mol \cdot K}$$

$$-\frac{\Delta G^\circ}{RT} = \ln K$$

$$K = e^{-\Delta G^\circ / RT} = e^{-8040\ \frac{J}{mol} \Big/ 8.314\ \frac{J}{mol \cdot K} \cdot 298\ K}$$

$$= 0.0390$$