Exercise 6.6
Free Energy Calculations

1. Calculate the free energy change for the dissolution of solid sodium hydroxide in water under standard conditions. Is this reaction thermodynamically allowed?

2. Calculate the free energy change for the production of $PCl_{5(g)}$ from red phosphorus and chlorine gas under standard conditions. Is this reaction thermodynamically allowed?

$$\Delta G_f^o(NaOH_{(s)}) = -379.53 \ \frac{kJ}{mol}$$

$$\Delta G_f^o(Na_{(aq)}^+) = -261.87 \ \frac{kJ}{mol}$$

$$\Delta G_f^o(OH_{(aq)}^-) = -157.30 \ \frac{kJ}{mol}$$

$$\Delta H_f^o(P_{(s,red)}) = -17.6 \ \frac{kJ}{mol}$$

$$\Delta H_f^o(PCl_{5(g)}) = -402 \ \frac{kJ}{mol}$$

$$S^o(P_{(s,red)}) = 22.8 \ \frac{J}{mol \cdot K}$$

$$S^o(PCl_{5(g)}) = 353 \ \frac{J}{mol \cdot K}$$
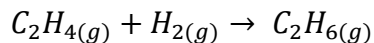
$$S^o(Cl_{2(g)}) = 223.0 \ \frac{J}{mol \cdot K}$$

3. The standard free energy change for the hydrogenation of ethene (C_2H_4) to ethane (C_2H_6) is $-101.25 \frac{kJ}{mol}$.

$$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$$

(a) Is this reaction thermodynamically allowed under standard conditions?

(b) What is the standard free energy of formation for ethene?

4. The standard free energy change for the hydrogenation of benzene (C_6H_6) to cyclohexane (C_6H_{12}) in the liquid phase is $-97.6 \frac{kJ}{mol}$.
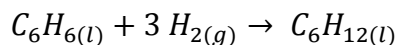
$$C_6H_{6(l)} + 3\,H_{2(g)} \rightarrow C_6H_{12(l)}$$

(a) Is this reaction thermodynamically allowed under standard conditions?

(b) What is the standard free energy of formation for cyclohexane?

$$\Delta G_f^o\left(C_2H_{6(g)}\right) = -32.89\frac{kJ}{mol}$$
$$\Delta G_f^o\left(C_6H_{6(l)}\right) = 124.5\frac{kJ}{mol}$$