18 • Chemical Equilibria

1. Consider the equilibrium: \(2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})\) \(K_{\text{eq}} = 4.36\)
   Calculate the value of \(Q\) for a situation in which the initial concentrations are \([\text{SO}_2] = 2.00 \text{ M}\), \([\text{O}_2] = 1.25 \text{ M}\), and \([\text{SO}_3] = 1.50 \text{ M}\).
   \[K_{\text{eq}} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]} = \frac{(1.50)^2}{(2.00)^2(1.25)} = 0.260\]
   Does this mixture shift toward the reactants or products to reach equilibrium? Why?
   \(Q = 2.60 < K_{\text{eq}} = 4.36\), shift to reactants because it has not reached equilibrium yet.

2. Using the same equilibrium as question 1, calculate the \(Q\) for a situation in which the concentrations are \([\text{SO}_2] = 0.200 \text{ M}\), \([\text{O}_2] = 0.150 \text{ M}\), and \([\text{SO}_3] = 3.25 \text{ M}\).
   \[Q = \frac{(3.25)^2}{(0.200)^2(0.150)} = 17.6\]
   Does this mixture shift toward the reactants or products to reach equilibrium? Why?
   \(Q = 17.6 > K_{\text{eq}} = 4.36\), shift to products because it is way past \(K_{\text{eq}}\) and to get to \(K_{\text{eq}}\) it must shift back toward the reactants.

3. Indicate how each of the following changes affects the amount of each gas in the system below, for \(\Delta H_{\text{reaction}} = +9.9\) kcal.
   \[
   \text{heat} + \text{H}_2(\text{g}) + \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g})
   \]
   a) addition of \(\text{CO}_2\)
   b) addition of \(\text{H}_2\text{O}\)
   c) addition of a catalyst
   d) increase in temperature
   e) decrease in the volume of the container

4. Consider the equilibrium: \(2\text{N}_2\text{O}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 4\text{NO}(\text{g})\)
   How will the amount of chemicals at equilibrium be affected by
   a) adding \(\text{N}_2\text{O}\)
   b) adding \(\text{He}\) (inert gas)
   c) increasing the volume of the container
   d) adding a catalyst

5. For the reaction, \(\Delta H = -57.2\) kJ/mol
   How will the concentration of each chemical be affected by
   a) adding \(\text{O}_2\) to the system
   b) adding heat to the system
   c) removing \(\text{H}_2\text{O}\) from the system
   d) decreasing the volume of the container