Chapter 12 – Equilibrium

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- Products can reverse into reactants:

  1. $\begin{array}{ll} 2\,NO_2 \longrightarrow N_2O_4 & (forward) \\ 2\,NO_2 \longleftarrow N_2O_4 & (reverse) \end{array}$

- Reaction rate is dependent on concentration (high concentration, fast rate; low concentration, slow rate)

- Forward rate vs. Reverse rate:

  1. Once equilibrium is reached, the concentrations stay the same, even though reactions continue (forward rate = reverse rate)

- Equilibrium Expressions (Only for gases and aqueous solutions)

  1. Ex. $N_2 + 3\,H_2 \rightleftharpoons 2\,NH_3$, where k_c is a concentration constant, and k_p is a pressure constant

$$\begin{aligned} k_c &= \frac{[NH_3]^2}{[N_2][H_2]^3} \\ k_p &= \frac{P_{NH_3}}{P_{N_2} \cdot P_{H_2}} \\ k_p &= k_c\,(RT)^{\Delta n} \end{aligned} \tag{1}$$

- If coefficients are multiplied by n, then:

$$k = k^n \tag{2}$$

- If the reaction is reversed, then:

$$k = \frac{1}{k} \tag{3}$$

- If the reaction occurs in multiple steps, multiply the individual k values by each other
- Important to note: liquids and solids are not included in the k expression, regard them as ones
- Ice $-$ $\begin{array}{c|l} \text{I} & \text{nitial} \\ \text{C} & \text{hange} \\ \text{E} & \text{quilibrium} \end{array}$
- k tells you about where the equilibrium lies
    1. If $k > 1$, the equilibrium is to the right
        (a) More product
    2. If $k < 1$, the equilibrium is to the left
        (a) More reactant
- Reaction Quotient (Q)
    1. Ratio of product to reactants at a set time
    2. Similar to k, but not necessarily at equilibrium line k
    3. If $Q < k$, need to form more product to get to equilibrium
    4. If $Q > k$, too much product made, must go in the other direction to get to equilibrium
    5. If $Q = k$, at equilibrium
- Le Chatelier's Principle
    1. When reactant or product is added, equilibrium shifts away from the side it was added from
    2. When reactant or product is removed, equilibrium shifts towards the side it was removed from
    3. Volume Change
        (a) Decrease Volume: Pressure goes up, equilibrium will shift to side with least gas molecules
        (b) Increase Volume: Pressure goes down, equilibrium will shift to side with most gas molecules
    4. Temperature
        (a) Exothermic: Whatever is done to temperature affects the right side
        (b) Endothermic: Whatever is done to temperature affects the left side
    5. Example: Heat + $\mathrm{UO_2(s)} + 4\,\mathrm{HF\,(g)} \rightleftharpoons \mathrm{UF_4(g)} + 2\,\mathrm{H_2O\,(g)}$, $\Delta H = 36[\mathrm{kJ}]$
        (a) Adding HF shifts right
        (b) Reducing heat shifts left
        (c) Increasing volume shifts left