Creating the Equation for the Equilibrium Constant

In the reaction, reactant A and B yields products C and D. The general equation is represented as the following:

$$a\,A + b\,B \rightleftarrows c\,C + d\,D$$

The letters a, b, c, and d represent the molar coefficients of the reaction. Using this equation, the equilibrium constant is determined by:

$$K_{eq} = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

Remember, the brackets indicate molar concentration. Coefficients in the chemical equation become exponents. Any solids or pure liquids that are in the reaction are not included because they have undefined molarities.

When the reaction is at equilibrium in the K_{eq} expression, this means that the rate of the forward and reverse reactions are the same. Recall that the rate of the reaction is the speed at which the reaction occurs.

$$\text{Rate } (aA + bB \rightarrow cC + dD) = \text{Rate } (cC + dD \rightarrow aA + bB)$$

At equilibrium, the concentrations are not necessarily equal. The product or reactant side may be favored. The favored substance has a higher concentration at equilibrium.

The concentration of the substances in the reaction is a measure of how many moles per liter of solution molecules exist. At higher concentrations, there are more molecules, so therefore more chances for collisions to occur to drive a reaction. At lower concentrations there are fewer molecules, so fewer collisions are produced.

The rate of the forward reaction can be described as:

$$\text{Rate} = k_{forward}\,[A]^a\,[B]^b$$

The rate of the reverse reaction can be described as:

$$\text{Rate} = k_{reverse}\,[C]^c\,[D]^d$$

Since the equation is at equilibrium, the forward and reverse rate are equal to each other.

$$k_{forward}\,[A]^a\,[B]^b = k_{reverse}\,[C]^c\,[D]^d$$

$$\frac{k_{reverse}\,[C]^c\,[D]^d}{k_{forward}\,[A]^a\,[B]^b} = K_{eq}$$

Effect of Changing Variables on K_{eq}

Changing temperature favors either forward or reverse reactions. Changing the temperature changes the rate constant. This means that temperature directly changes the value of K_{eq}. At constant temperature, changing the equilibrium concentration does not affect K_{eq} because the rate constants are not affected by the concentration changes.

When the concentration of one of the participants is changed, the concentration of the others vary in such a way as to maintain a constant value for the K_{eq}.

Summary Points

- A value of K_{eq} greater than 1 indicates that at equilibrium there is a higher concentration of products relative to the concentration of reactants.
- A value of K_{eq} less than 1 indicates that at equilibrium there is a lower concentration of products relative to the concentration of reactants.
- A large K_{eq} indicates that the forward reaction rate constant is large. A higher reaction rate constant means that the products are more likely to react at a given temperature. The forward reaction increases, so the products are favored in the reaction. When the value of K_{eq} is infinity, this means the reaction fully goes to the products and the reaction is irreversible.
- A small K_{eq} indicates that the reverse reaction rate constant is large. The reactants are favored to form in the reaction.