Types of chemical reactions and their equilibrium constants

Solubility/precipitation – always described by solubility reaction

$$AgCl(s) \leftrightarrows Ag^+(aq) + Cl^-(aq)$$

with the equilibrium constant called the solubility product

$$K_{sp} = [Ag^+][Cl^-] = 1.8\times10^{-10}$$

Acid/base – described by either the reaction of the acid with water

$$CH_3COOH(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + CH_3COO^-(aq)$$

with the equilibrium constant called the acid dissociation constant

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]} = 1.8\times10^{-5}$$

or by the reaction of the base with water

$$NH_3(aq) + H_2O(l) \leftrightarrows NH_4^+(aq) + OH^-(aq)$$

which gives the base dissociation constant

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = 1.8\times10^{-5}$$

A special case is that of water reacting with itself in a proton-transfer reaction

$$2H_2O(l) \leftrightarrows H_3O^+(aq) + OH^-(aq)$$

which is characterized by water's dissociation constant

$$K_w = [H_3O^+][OH^-] = 1.00\times10^{-14}$$

Complex formation/dissociation – usually described by the formation reaction in either a step-wise fashion in which ligands bind to the metal one-by-one

$$Ag^+(aq) + NH_3(aq) \leftrightarrows Ag(NH_3)^+(aq) \qquad Ag(NH_3)^+(aq) + NH_3(aq) \leftrightarrows Ag(NH_3)_2^+(aq)$$

with corresponding step-wise formation constants

$$K_1 = \frac{[Ag(NH_3)^+]}{[Ag^+][NH_3]} = 2040 \qquad K_2 = \frac{[Ag(NH_3)_2^+]}{[Ag(NH_3)^+][NH_3]} = 8130$$

or as an overall formation constant in which the ligands bind simultaneously

$$Ag^+(aq) + 2NH_3(aq) \leftrightarrows Ag(NH_3)_2^+(aq)$$

with a corresponding overall formation constant

$$\beta_2 = \frac{[Ag(NH_3)_2^+]}{[Ag^+][NH_3]^2} = K_1 \times K_2 = 1.66\times10^7$$