Exercise 8: Equilibrium, pH, acids, buffers

1. An ionic substance dissolving into its component ions in water can be written as a chemical equation.

a. Consider the dissolution of calcium hydroxide. Complete and balance the chemical equation describing this dissolution, and don’t forget to indicate charges on ionic species:

\[ \text{Ca(OH)}_2 (s) \]

b. Write the equilibrium constant expression of the equation in part a. Hint: is a pure substance supposed to be included in the expression?

c. For dissolved ionic substances, \( K_{eq} \) is written as \( K_{sp} \) and is read “the solubility product constant”, but means exactly the same thing as an equilibrium constant. In any table of \( K_{sp} \)'s, the value of \( K_{sp} \) at 25°C for calcium hydroxide is \( 1.3 \times 10^{-6} \). For a 1.0 M solution of calcium hydroxide at 25°C, and given the equilibrium expression in part b, determine the concentration of the calcium ion and the hydroxide ion at equilibrium of this solution. Hint: these two numbers will not be the same!

d. Suppose sodium hydroxide solution were poured into the calcium hydroxide solution. The sodium hydroxide solution, of course, contains a lot of hydroxide ions. According to LeChatelier’s Principle, what macroscopic changes would be visible in the mixture? In other words, what happens?
2. a. Write the chemical equation that shows the **dissociation** of acetic acid (HC₂H₃O₂) into hydrogen and acetate ions. Don’t forget to indicate species charges, as appropriate, and make sure the equation is balanced.

b. Write the **equilibrium constant expression** for the dissociation of acetic acid.

c. For acids, $K_{eq}$ is written as $K_a$ and is read “the acid dissociation constant”, but means exactly the same thing as an equilibrium constant. In any table listing $K_a$’s, the value of $K_a$ at 25°C for acetic acid is $1.8 \times 10^{-5}$. For a 1.0 M solution of acetic acid at 25°C, and the equilibrium expression in part b, determine the **concentration of the hydrogen ion** at equilibrium of this solution. Hint: there is a significant amount of algebra, including the use of the **quadratic formula**.
3. a. To treat extreme cases of scurvy (caused by a Vitamin C deficiency), administration of a 0.100 M solution of ascorbic acid (we’ll write it as “HAsc”, since the ascorbate ion has a complex formula) are prescribed. $K_a=7.9 \times 10^{-5}$ for ascorbic acid. Write the dissociation equation for ascorbic acid (remember that it is an equilibrium process!).

b. Write the equilibrium expression for $K_a$ for ascorbic acid.

c. Using the expression in part b, calculate the pH of a 0.100 M solution of ascorbic acid. If the human stomach can handle ingested materials with pH greater than 2, is the ascorbic acid solution too acidic to drink?

d. The crucial part of the ascorbic acid molecule for human physiology is the ascorbate ion. Would a solution of sodium ascorbate (use the formula NaAsc) be acidic, basic or neutral? Show the appropriate chemical equations that led you to your conclusion.
4. Write a recipe to make 500. mL of an acetic acid (HC$_2$H$_3$O$_2$ – molar mass 60.05 g/mol) / sodium acetate (NaC$_2$H$_3$O$_2$ – molar mass 82.03 g/mol) buffer with a pH of 5.0. The $K_a$ of acetic acid is $1.8 \times 10^{-5}$. You must state the volume of 12.0 M acetic acid and the number of grams of sodium acetate you will need, and demonstrate that the pH of the resulting solution will be 5.0.