Weak Bases

A weak base is a compound that reacts incompletely with water to form an equilibrium that includes OH^- ions according to the following general equation.

$$B(aq) + H_2O(l) \Leftrightarrow OH^-(aq) + HB^+(aq)$$

For example, ammonia is a weak base.

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

Ionization Constants for Weak Bases

Weak bases like ammonia (NH_3) and hydrazine (N_2H_4) form dynamic equilibria in aqueous solutions. As such, the reaction of a weak base with water results in an equilibrium law expression and an equilibrium constant.

The equilibrium constant for a weak base is known as the **base ionization constant** (K_b). Consider the equilibrium reaction of ammonia with water.

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

The equilibrium law expression for this reaction is written as,

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

The Relationship Between K_a and K_b

It can be shown that, for acids and bases whose chemical formulas differ only by a hydrogen (i.e. conjugate acid-base pairs),

$$K_a \times K_b = K_W$$

where $K_W = 1.0 \times 10^{-14}$ at $25°C$.

This relationship allows us to convert the K_a values of acids into the K_b values of their conjugate bases (and vice versa). Standard acid-base tables typically list only the K_a of the acids. If you need to know the K_b of a base, first look up the K_a of its conjugate acid, then use the above equation to convert it.

Example 1

What is the value of the base ionization constant for the acetate ion (CH_3COO^-) at $25°C$?

The pH of Weak Base Solutions

Just as we used the acid ionization constant to convert between pH and $\left[H^+\right]$, we can use the base ionization constant to determine the pH, pOH, $\left[H^+\right]$, and $\left[OH^-\right]$ of solutions of weak bases.

Example 2
Calculate the pH of a $0.10\ mol/L$ aqueous solution of hydrazine (N_2H_4), a weak base. The K_b for hydrazine is 1.7×10^{-6}.

Worksheet

1. The K_b for hydrazine (N_2H_4), a rocket fuel, is 1.7×10^{-6}. What is the K_a of its conjugate acid ($N_2H_5^+$)?

2. Use information from the Relative Strengths of Brønsted-Lowry Acids and Bases table and K_W to calculate the base ionization constant of the following bases.

   a) iodate ion (IO_3^-).

   b) nitrite ion (NO_2^-).

   c) benzanoate ion ($C_6H_5COO^-$).

3. Morphine ($C_{17}H_{19}NO_3$) is a weak base and a powerful painkiller. A solution of morphine has a concentration of $0.01\ mol/L$. Determine the pH of this solution. The K_b for morphine is 7.5×10^{-7}.

4. Calculate the pH and $\left[H^+\right]$ of a $0.30\ mol/L$ solution of butanoic acid ($HC_4H_7O_2$). The K_a of butanoic acid is 1.52×10^{-5}.

5. Strychnine ($C_{21}H_{22}N_2O_2$) is a weak base but a powerful poison. Calculate the pH of a $0.001\ mol/L$ solution of strychnine. The K_b of strychnine is 1.0×10^{-6}.

Answers

1. 5.9×10^{-9}

2. (a) 5.9×10^{-14} (b) 2.2×10^{-11} (c) 1.5×10^{-10}

3. 9.94

4. $\left[H^{+}\right]=2.1\times10^{-3}\ mol/L,\ pH=2.67$

5. 9.5