Acid and Base Dissociation Constants

Read from **Lesson 3b:** Dissociation Constants in the **Chemistry Tutorial Section, Chapter 15** of **The Physics Classroom**
Also, note the Table of Dissociation Constants: K_a and K_b Values on the Physics Classroom Reference Page

Introduction

- A dissociation constant quantifies how much an acid or base ionizes in water: they measure the strength of acids and bases.
- K_a is for acids; K_b is for bases.
- Strong acids/bases dissociate completely (K_a or $K_b \gg 1$).
- Weak acids/bases dissociate partially (K_a or $K_b < 1$).

Acid Dissociation (K_a)

- **Weak acids follow a reversible reaction:**

$$HC_2H_3O_2(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_2H_3O_2^-(aq)$$

The K_a expression is:

$$K_a = \frac{[H_3O^+] * [C_2H_3O_2^-]}{[HC_2H_3O_2]}$$

- **A larger K_a means more dissociation and a stronger weak acid.**

Example:
HNO_2: $K_a = 7.2\times10^{-4}$ (stronger weak acid)
$HC_2H_3O_2$: $K_a = 1.8\times10^{-5}$ (weaker weak acid)

Base Dissociation (K_b)

- **Weak bases follow a reversible reaction:**

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

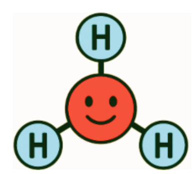
The K_b expression is:

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

- **A larger K_b means more dissociation and a stronger weak base.**

Example:
$C_5H_{10}NH$: $K_b = 1.3\times10^{-3}$ (stronger weak base)
NH_3: $K_b = 1.8\times10^{-5}$ (weaker weak base)

Polyprotic Acids



- Monoprotic acids release one H^+ ion.
- Polyprotic acids release multiple H^+ ions in steps, each with its own Ka:
- Carbonic acid (H_2CO_3): $Ka_1 = 4.5\times10^{-7}$, $Ka_2 = 4.7\times10^{-11}$
- Phosphoric acid (H_3PO_4): $Ka_1 = 7.1\times10^{-3}$, $Ka_2 = 6.3\times10^{-8}$, $Ka_3 = 2.4\times10^{-12}$
- Sulfuric acid (H_2SO_4): First dissociation is strong; second is weak ($Ka_2 = 1.1\times10^{-2}$)

Calculations: How to Determine K_a of a Weak Acid from pH

1. Write the balanced chemical equation showing the dissociation of the weak acid into its ions.
2. Write the expression for K_a based on the equation from Step 1.
3. Calculate the equilibrium concentration of hydronium ions, $[H_3O^+]$, using the given pH.
4. The $[H_3O^+]_{equilibrium} = [anion]_{equilibrium}$. Since each molecule of acid that dissociates produces one hydronium ion and one anion, their concentrations at equilibrium are equal.
5. Assume $[Acid]_{eq} \approx [Acid]_{initial}$. Because the acid is weak, only a small fraction dissociates—so the initial concentration remains virtually unchanged.
6. Substitute all equilibrium concentrations into the K_a expression from Step 2 and solve for the K_a value.

Questions

1. Why don't strong acids require a reversible reaction arrow in their dissociation equations?

Acids and Bases

2. Consider two different weak acids, each with a concentration of 0.25 M. How does the pH of their solutions vary based on the magnitude of their Ka values?

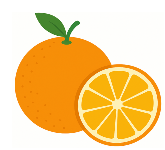
3. An acid has a Ka of 3.2×10^{-7}. Which of the following statements are true?
   a. The acid is strong and dissociates completely.
   b. The acid is weak and only partially dissociates.
   c. The acid has a pH greater than 7.
   d. The acid has a pH less than 7

4. Using the **Table of Dissociation Constants: K_a and K_b Values on the Physics Classroom Reference Page**, complete the table below and rank the acids from strongest to weakest.

Name of Acid	Formula	Ka
Acetic Acid	$HC_2H_3O_2$	1.8×10^{-5}
Benzoic Acid		
Cyanic Acid		
Formic Acid		
Iodic Acid		
Lactic Acid		

Ranking:

5. Citric acid, $H_3C_6H_5O_7$, undergoes three dissociation steps, each with its own Ka value. Based on these values obtained from the Reference Table, which step is the least favorable, and what explains its lower tendency to dissociate?



6. A 0.135 M solution of a weak acid has a pH of 4.2.
   a. Calculate the acid dissociation constant, Ka, for this acid.

   b. Based on your result and the Reference Table, identify which weak acid this could be.