Acid-Base Equilibria

Read from **Lesson 2 Acid-Base Equilibria** in the **Chemistry Tutorial** Section**, Chapter 16** of **The Physics Classroom**:
Part a: Weak Acid and Weak Base Dissociation
Part b: Percent Dissociation and K_a and K_b
Part c: Dissociation of Polyprotic Acids

Part 1: Weak Acid and Weak Base Dissociation

- Weak acids and bases only partially dissociate in water.
- Equilibrium is established between dissociated ions and undissociated molecules.
- Use $\mathbf{K_a}$ (acid dissociation constant) and $\mathbf{K_b}$ (base dissociation constant) to quantify dissociation.
- ICE tables (Initial, Change, Equilibrium) help track concentrations and solve for unknowns.

Problem-Solving Strategy

- Write the balanced chemical equation.
- Write the equilibrium expression ($\mathbf{K_a}$ or $\mathbf{K_b}$).
- Set up an ICE table.
- Substitute equilibrium values into the $\mathbf{K_a}$ / $\mathbf{K_b}$ expression.
- Solve for x (ion concentration), then calculate pH or pOH.
- Apply the **5% Rule**: If x < 5% of initial concentration, simplify algebra by assuming [HA] ≈ initial.
- Use $pH = -\log[H_3O^+]$ and $pOH = -\log[OH^-]$; pH + pOH = 14.

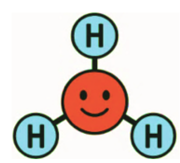
Part 2: Percent Dissociation and K_a/K_b Relationships

- **Percent dissociation** = (amount dissociated / initial concentration) × 100
- Strong acids: ~100% dissociation; weak acids: <5% typically.
- Percent dissociation varies with concentration—more dilute = higher % dissociation.

Problem-Solving Strategy

- Use ICE table to define x (amount dissociated).
- Calculate K_a using equilibrium concentrations.
- Use pH to find $[H_3O^+]$ and back-calculate K_a or % dissociation.
- Use $[H_3O^+] = 10^{-pH}$ to find x.

Part 3: Dissociation of Polyprotic Acids



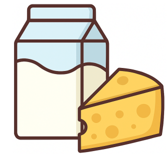
- **Polyprotic acids** donate more than one proton (e.g., H_2CO_3, H_3PO_4).
- Dissociation occurs stepwise, each with its own K_a:
- $K_{a1} > K_{a2} > K_{a3}$
- Only the first dissociation significantly affects pH.

Problem-Solving Strategy

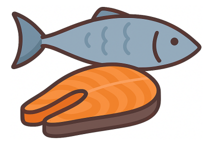
- Analyze each dissociation step separately.
- Use ICE tables and K_a values for each step.
- Apply the 5% Rule to simplify calculations.
- Determine pH from total $[H_3O^+]$ (usually dominated by first step).
  - For diluted polyprotic acids, check if percent dissociation >5%—may require quadratic solutions.
  - Amphiprotic species (e.g., HCO_3^-) can act as both acid and base.

Solution Equilibria

Part 1: Questions



1. Lactic acid, $\mathbf{HC_3H_5O_3}$, is found in yogurt and cheese. A 0.500 M solution of lactic acid has a **pH of 2.09**. What is the $\mathbf{K_a}$ of lactic acid?



2. Many fish contain methylamine, CH_3NH_2. Methylamine's K_b is 4.2×10^{-4} at 25°C.
   a. What is the **pH** of a 0.0500 M solution of methylamine?

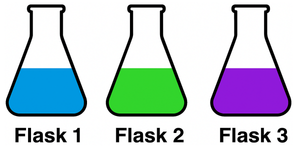
   b. What is the **percent dissociation** in this solution of methylamine?

   c. If the solution were instead 0.500 M, what would the new **pH** be?

   d. How does the **percent dissociation change** and **why**?

Solution Equilibria

Part 2: Questions



Three Erlenmeyer flasks sit on the lab bench, each containing 250.0 mL of a 0.100 M solution of a different compound. Flask **1** contains **HNO_3** (nitric acid) , Flask **2** contains **NH_3** (ammonia), and Flask **3** contains **$H_2C_4H_4O_4$** (succinic acid). Sally Kon and Aaron Agin are discussing the relative pH values of the three solutions. Aaron claims that **Flask 3** must have the lowest pH because its compound contains four hydrogen atoms per molecule. Sally disagrees and explains why Aaron's reasoning is flawed. Answer the following questions and complete the needed calculations—just as Sally did—to determine which solution truly has the lowest pH. Show all relevant work. K_a or K_b dissociation constants can be found on the Physics Classroom Reference Page under the Chemistry Tutorial section.

1. Flask 1:
   a. Write both dissociation equation and the K_a or K_b expression(s) (if applicable) for HNO_3.

   b. Determine the equilibrium concentrations of ions in this solution. Use an ICE Table if applicable.

   c. Determine the pH of the HNO_3 solution in Flask 1.

2. Flask 2:
   a. Write both dissociation equation and the K_a or K_b expression(s) (if applicable) for NH_3.

   b. Determine the equilibrium concentrations of ions in this solution. Use an ICE Table if applicable.

   c. Determine the pH of the NH_3 solution in Flask 2.

Solution Equilibria

3. Flask 3:

   a. Write both dissociation equation and the K_a or K_b expression(s) (if applicable) for $H_2C_4H_4O_4$.

   b. Determine the equilibrium concentrations of ions in this solution. Use an ICE Table if applicable.

   c. Determine the pH of the $H_2C_4H_4O_4$ solution in Flask 3.

4. Which flask has the lowest pH?

5. Why was Aaron's reasoning flawed?