

Dissociation of Carbonic Acid (H_2CO_3)

Subject: Chemistry - Acid-Base Equilibria

Given:

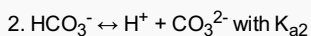
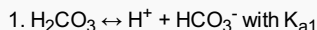
Initial concentration of H_2CO_3 (carbonic acid) = 0.180 M

$$K_{a1} \text{ for } \text{H}_2\text{CO}_3 = 4.3 \times 10^{-7}$$

$$K_{a2} \text{ for } \text{H}_2\text{CO}_3 = 5.6 \times 10^{-11}$$

Dissociation Steps:

Carbonic acid dissociates in two steps:



Step 1: Dissociation Equilibria Setup:

$$K_{a1} = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$$

Assuming $[\text{H}^+] = [\text{HCO}_3^-] = x$:

$$K_{a1} = \frac{x^2}{0.180 - x}$$

Since K_{a1} is small, x is small compared to 0.180, so $0.180 - x \approx 0.180$:

$$4.3 \times 10^{-7} = \frac{x^2}{0.180}$$

Solving for x :

$$x^2 = (4.3 \times 10^{-7}) \times 0.180$$

$$x^2 = 7.74 \times 10^{-8}$$

$$x = \sqrt{7.74 \times 10^{-8}}$$

$$x = 8.8 \times 10^{-4} \text{ M}$$

Therefore, $[\text{H}^+] = [\text{HCO}_3^-] = 8.8 \times 10^{-4} \text{ M}$

Step 2: Calculate $[\text{CO}_3^{2-}]$ using K_{a2} :

$$K_{a2} = \frac{[\text{H}^+][\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$$

Let y represent the concentration of $[\text{CO}_3^{2-}]$:

$$K_{a2} = \frac{(8.8 \times 10^{-4}) y}{8.8 \times 10^{-4}}$$

$$K_{a2} = y$$

So:

$$y = K_{a2} = 5.6 \times 10^{-11} \text{ M}$$

Thus, $[\text{CO}_3^{2-}] = 5.6 \times 10^{-11} \text{ M}$

Step 3: Calculate $[\text{OH}^-]$ using K_w :

Using the relationship:

$$K_w = [\text{H}^+][\text{OH}^-]$$

$$1.0 \times 10^{-14} = (8.8 \times 10^{-4})[\text{OH}^-]$$

Solving for $[\text{OH}^-]$:

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14}}{8.8 \times 10^{-4}}$$

$$[\text{OH}^-] = 1.14 \times 10^{-11} \text{ M}$$

Therefore, $[\text{OH}^-] = 1.14 \times 10^{-11} \text{ M}$

Final Solution:

$$[\text{CO}_3^{2-}] = 5.6 \times 10^{-11} \text{ M}$$

$$[\text{H}_3\text{O}^+] = 8.8 \times 10^{-4} \text{ M}$$

$$[\text{OH}^-] = 1.14 \times 10^{-11} \text{ M}$$