CheggSolutions - Thegdp

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} for H_2CO_3 = 4.3×10^{-7}

K_{a2} for H_2CO_3 = 5.6×10^{-11}

Dissociation Steps:

Carbonic acid dissociates in two steps:

1. $H_2CO_3 \leftrightarrow H^+ + HCO_3^-$ with K_{a1}

2. $HCO_3^- \leftrightarrow H^+ + CO_3^{2-}$ with K_{a2}

Step 1: Dissociation Equilibria Setup:

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

Assuming $[H^+] = [HCO_3^-] = x$:

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

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

4.3×10^{-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 = \(\sqrt{7.74 \times 10^{-8}}\)

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

Therefore, $[H^+] = [HCO_3^-] = 8.8 \times 10^{-4}$ M

Step 2: Calculate $[CO_3^{2-}]$ 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:

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

Thus, $[CO_3^{2-}] = 5.6 \times 10^{-11}$ M

Step 3: Calculate $[OH^-]$ using Kw:

Using the relationship:

$K_w = [H^+][OH^-]$

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

Solving for $[OH^-]$:

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

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

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

Final Solution:

$[CO_3^{2-}] = 5.6 \times 10^{-11}$ M

$[H_3O^+] = 8.8 \times 10^{-4}$ M

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