#63365 Chemistry, General Chemistry

Determine the concentrations of the following ionic species present in a 0.311 M solution of the diprotic acid H_2SO_3. For H_2SO_3, Ka1 = 1.4E-2, Ka2 = 6.3E-8.

What is the H_3O^+ ion concentration?

the tolerance is +/-2%

What is the HSO_3^- ion concentration?

the tolerance is +/-2%

What is the SO_3^{2-} ion concentration?

Answer:

$H_2SO_3 + H_2O \Leftrightarrow H_3O^+ + HSO_3^-$ $\quad Ka_1 = 1.4 \cdot 10^{-2}$
$HSO_3^- + H_2O \Leftrightarrow H_3O^+ + SO_3^{2-}$ $\quad Ka_2 = 6.3 \cdot 10^{-8}$
Because Ka1 is much greater than Ka2, the amount of H_3O^+ produced (and the amount of HSO_3^- reacted) in Step 2 is negligible compared to the amount from Step 1.
The first hydrolysis step will undergo as follows:
Molarity . . . . .$H_2SO_3 + H_2O \Leftrightarrow H_3O+ + HSO_3^-$
Initial . . . . . .0.311 . . . . . .0 0
Change . . ..-x . . . . . .x x
Equilibrium . . .0.311-x . . . .. . .x x
$Ka1 = [H_3O^+][HSO_3^-] / [H_2SO_3] = (x)(x) / (0.311-x) = 1.4 \cdot 10^{-2}$
$x^2 = (1.4 \cdot 10^{-2})(0.311-x)$
$x^2 = -0.014x + 0.0068$
$x^2 + 0.013x - 0.0043 = 0$
x = 0.072 and -0.059
$[H_2SO_3] = 0.311 - x = 0.311 - 0.072 = 0.239$ M
$[H_3O^+] = [HSO_3^-] = x = 0.072$ M
Since $[H_3O^+][OH^-] = 1.0 \times 10^{-14}$, then $[OH^-] = (1.0 \cdot 10^{-14} / 0.072) = 1.4 \cdot 10^{-13}$
To get SO_3^{2-}, we need to look at the second reaction.
Molarity . . . . .$H_SO_3- + H_2O \Leftrightarrow H_3O^+ + SO_3^{2-}$
Initial . . . . . 0.072 . . . . 0.072 . 0
Change . . . . . .-x . . . . .x x
Equilibrium . . .0.072-x . . . . 0.072+x . . x
$Ka2 = [H_3O^+][SO_3^{2-}] / [HSO_3^-] = (0.072+x)(x) / (0.072-x) = 6.3 \times 10^{-8}$
As Ka2 is small (10^{-8}), then the x term will be small compared to 0.072 and we can drop it from 0.072-x and 0.072+x.
$0.072x / 0.072 = x = 6.3 \times 10^{-8}$.
$[SO_3^{2-}] = x = Ka2 = 6.3 \times 10^{-8}$.