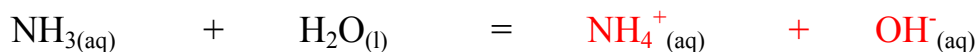


Chemistry 534

Exploration Problem

MAIN PROBLEM Given that the K_b of NH_3 is 1.8×10^{-5} , calculate the K_a of the ammonium ion, NH_4^+ .

- 1) First write an equation showing that NH_3 is a Bronsted base in water. Complete the following:



- 2) Now write a K_b expression for the above.

$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$$

- 3) Multiply both the numerator and denominator by $[\text{H}^+]$.

$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-][\text{H}^+]}{[\text{NH}_3][\text{H}^+]}$$

- 4) Substitute K_w into your answer for #3,. Remember what K_w equals.

$$\text{Since } K_b = \frac{[\text{NH}_4^+][\text{OH}^-][\text{H}^+]}{[\text{NH}_3][\text{H}^+]} \text{ and } K_w = [\text{OH}^-][\text{H}^+]$$

$$K_b = \frac{[\text{NH}_4^+]K_w}{[\text{NH}_3][\text{H}^+]}$$

- 5) Write an equilibrium equation showing how NH_4^+ acts as an acid.



- 6) Write a K_A expression for your equation in #5.

$$K_A = \frac{[NH_3][H^+]}{[NH_4^+]}$$

7) Write an expression for $\frac{1}{K_A}$

$$\frac{1}{K_A} = \frac{[NH_4^+]}{[NH_3][H^+]}$$

8) Substitute your answer from #7 into your expression for #4

$$\text{Since } K_b = \frac{[NH_4^+]K_w}{[NH_3][H^+]} \quad \text{and} \quad \frac{1}{K_A} = \frac{[NH_4^+]}{[NH_3][H^+]}$$

$$\text{Then } K_b = \frac{K_w}{K_A} \quad \text{or} \quad K_A = \frac{K_w}{K_b}$$

9) Now solve the main problem at the top of the page (Get K_A for ammonium ion)

$$K_A = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$$

SPINOFF PROBLEM Calculate the percent of NH_4^+ molecules ionized (also known as percent dissociation) in a 0.10 M solution. (Use your K_A from step 9)

$$K_A = \frac{[NH_3][H^+]}{[NH_4^+]} = \frac{[x][x]}{[0.10-x]} = 5.6 \times 10^{-10}$$

Cross multiply; use quadratic to solve for x.

$$x = 7.5 \times 10^{-6}$$

The % that splits up = $7.5 \times 10^{-6} / 0.10 * 100 = 0.0070\%$ (very small!)