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:

$NH_{3(aq)} + H_2O_{(l)} = NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

2) Now write a K_b expression for the above.

$$\mathbf{K_b} = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

3) Multiply both the numerator and denominator by $[H^+]$.

$$\mathbf{K_b} = \frac{[NH_4^+][OH^-][H^+]}{[NH_3][H^+]}$$

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

Since $\mathbf{K_b} = \frac{[NH_4^+][OH^-][H^+]}{[NH_3][H^+]}$ **and Kw = $[OH^-][H^+]$**

$$\mathbf{K_b} = \frac{[NH_4^+]K_w}{[NH_3][H^+]}$$

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

$NH_4^+{}_{(aq)} = NH_{3(aq)} + H^+{}_{(aq)}$

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

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

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

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

Then $K_b = \frac{K_w}{K_A}$ or $K_A = \frac{K_w}{K_B}$

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

$K_A = \frac{K_w}{K_B} = \frac{1.0X10^{-14}}{1.8X10^{-5}} = 5.6 \text{ X } 10^{-10}$

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)

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

Cross multiply; use quadratic to solve for x.

$x = 7.5 \text{ X} 10^{-6}$

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