

## Acid/Base Properties of a Pharmaceutical Compound

Many pharmaceutically interesting compounds are weak acids or weak bases, a fact of some importance when preparing them for use by the public. For example, if the active ingredient in a nasal spray is too acidic, then the preparation might include an additional ingredient to neutralize some of the acid; after all, no one wants to spray something as acidic as, say, lemon juice up his or her nose!

Pseudoephedrin is a central nervous system stimulant used in many cold and allergy tablets. In its molecular form it is a weak base (it is an amine), which, for convenience, we may represent as B. In water, the following equilibrium reaction exists



The Merck Index reports that a 0.030 M solution of pseudoephedrin has an equilibrium pH of 11.44. What is the value of  $K_b$  for this compound?

*Answer.* With a pH of 11.44, the pOH is 2.56 and the equilibrium concentration of  $OH^-$  is  $2.75 \times 10^{-3}$  M. This value goes in the change column for  $OH^-$  and determines the change for B and  $HB^+$

	B	+	H <sub>2</sub> O	⇌	OH <sup>-</sup>	+	HB <sup>+</sup>
I	0.030 M		-		0		0
C	$-2.75 \times 10^{-3}$ M		-		$2.75 \times 10^{-3}$ M		$2.75 \times 10^{-3}$ M
E	0.02725		-		$2.75 \times 10^{-3}$ M		$2.75 \times 10^{-3}$ M

Now that we have the equilibrium concentrations, we substitute into the  $K_b$  expression

$$K_b = \frac{[HB^+][OH^-]}{[B]} = \frac{(2.75 \times 10^{-3})^2}{0.02725} = 2.77 \times 10^{-4}$$

Because its base form is only slightly soluble in water, pseudoephedrin typically is dispensed in its weak acid form,  $HB^+$ . Pseudoephedrin hydrochloride, therefore, is an ionic compound consisting of protonated pseudoephedrin,  $HB^+$ , and  $Cl^-$  as a counter ion. The formula for this often is written as B·HCl; don't confuse this with the strong acid HCl. A solution of pseudoephedrin hydrochloride, therefore, is acidic due to the presence of  $HB^+$ . Write the  $K_a$  reaction responsible for making the solution acidic and report the value for  $K_a$ .

*Answer.* The reaction is  $BH^+ + H_2O \rightleftharpoons H_3O^+ + B$ , for which the equilibrium constant is

$$K_a = K_w/K_b = (1.00 \times 10^{-14})/(2.77 \times 10^{-4}) = 3.61 \times 10^{-11}$$

Suppose you dissolve three tablets of Sudafed<sup>®</sup>, each containing 30.0 mg of pseudoephedrin hydrochloride, in 200.0 mL of water. What is the pH of the resulting solution? The molar mass for pseudoephedrin hydrochloride is 201.7 g/mol.

*Answer.* Begin by finding the concentration of pseudoephedrin hydrochloride, which is

$$\frac{3 \text{ tablets} \times \frac{0.030 \text{ g}}{\text{tablet}} \times \frac{1 \text{ mole}}{201.7 \text{ g}}}{0.200 \text{ L}} = 2.23 \times 10^{-3} \text{ M}$$

Taking this as the initial concentration of  $\text{HB}^+$ , we solve the problem

	$\text{HB}^+$	+	$\text{H}_2\text{O}$	$\rightleftharpoons$	$\text{H}_3\text{O}^+$	+	B
I	$2.23 \times 10^{-3} \text{ M}$		-		0		0
C	-X		-		+X		+X
E	$2.23 \times 10^{-3} - X$		-		X		X

Substituting into the  $K_a$  expression and solving gives

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{B}]}{[\text{HB}^+]} = \frac{X^2}{2.23 \times 10^{-3} - X} = 3.61 \times 10^{-11}$$

Assuming that  $2.23 \times 10^{-3} - X \approx 2.23 \times 10^{-3}$  simplifies this to

$$K_a = \frac{X^2}{2.23 \times 10^{-3}} = 3.61 \times 10^{-11}$$

which gives

$$X = 2.84 \times 10^{-7}$$

Checking our assumption, we find that this produces an error of

$$\% \text{error} = \frac{2.23 \times 10^{-3} - (2.23 \times 10^{-3} - 2.84 \times 10^{-7})}{2.23 \times 10^{-3}} \times 100 = 0.01\%$$

which is acceptable. The concentration of  $\text{H}_3\text{O}^+$  is X, thus

$$[\text{H}_3\text{O}^+] = 2.84 \times 10^{-7} \quad \text{pH} = 6.55$$