Weak Acids and Bases

K_a

- Ionization of weak acids is not complete, as shown by the reversible arrow.
- $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$
- The extent of ionization can be represented using an equilibrium constant.
- K_a is called an acid ionization constant

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$$

Measuring Strengths of Weak Acids

* Stronger acids have large K_a
* Weaker acids have smaller K_a

Percent Ionization

* Ka is one measure of acid strength.
* % ionization is another measure of acid strength.

$$\%\ \text{Ionization} = \frac{[H+]\ \text{at equilibrium}}{\text{initial concentration}} \times 100$$

Example

* Propanoic acid, CH_3CH_2COOH, is a weak acid. 0.10 mol/L solution of propanoic acid had a pH of 2.96. Calculate the percent ionization for the acid.
* $CH_3CH_2COOH_{(aq)} \rightleftharpoons CH_3CH_2COO^-_{(aq)} + H^+_{(aq)}$

Solution

$$CH_3CH_2COOH_{(aq)} \rightleftharpoons CH_3CH_2COO^-{}_{(aq)} + H^+{}_{(aq)}$$

I	0.1	0	0
C	-x	+x	+x
E	0.1-x	x	x

Solution

- Calculate the $[H_3O^+]$ using pH
- $[H_3O^+] = 10^{-pH}$
- $[H_3O^+] = 10^{-2.96}$
- $[H_3O^+] = 1.1 \times 10^{-3}$ mol/L

* Since H_3O^+ is formed by the ionization of propanoic acid, this would be the equilibrium concentration

Solution

$$CH_3CH_2COOH_{(aq)} \rightleftharpoons CH_3CH_2COO^-_{(aq)} + H^+_{(aq)}$$

I	0.1	0	0
C	-x	+x	+x
E	$0.1 - 1.1 \times 10^{-3}$	1.1×10^{-3}	1.1×10^{-3}

Solution

* Calculate K_a

$$K_a = \frac{[C_2H_5OO^-][H_3O^+]}{[C_2H_5OOH]}$$

$$K_a = \frac{[1.1 \times 10^{-3}]^2}{[0.1 - 1.1 \times 10^{-3}]}$$

$$K_a = 1.2 \times 10^{-5}$$

Solution

* Calculate the percent ionization

$$\text{Percent Ionization} = \frac{[C_2H_5COO^-]_{ionized}}{[C_2H_5COOH]_{initial}} \times 100$$

$$\text{Percent Ionization} = \frac{1.1 \times 10^{-3}\ M}{0.1\ M} \times 100$$

Percent Ionization = 1.1%

Measuring Strengths of Weak Bases, K_b

* The equilibrium constant is given the subscript "b" to indicate that the equilibrium involves base ionization K_b is called base ionization constant.

Measuring Strengths of Weak Bases, K_b

* Stronger bases have large K_b
* Weaker bases have smaller K_b

Example

* Aniline, $C_6H_5NH_{2(l)}$ is used in the manufacturing of dyes. When dissolved in water it becomes a weak base. When a solution containing 0.0537 mol/L of aniline is prepared, the pH was determined to be 8.68. What is the K_b for aniline?

Solution

$$C_6H_5NH_{2(aq)} \rightleftharpoons C_6H_5NH_3^+{}_{(aq)} + OH^-{}_{(aq)}$$

I	0.0537	0	0
C	-x	+x	+x
E	0.0537-x	x	x

Solution

* Calculate the $[OH^-]$ using pH
* pOH = 14 - 8.68
* pOH=5.32
* $[OH^-] = 10^{-pOH}$
* $[OH^-] = 10^{-5.32}$
* $[OH^-] = 4.79 \times 10^{-6}$ mol/L

Solution

$$C_6H_5NH_{2(aq)} \rightleftharpoons C_6H_5NH_3^+{}_{(aq)} + OH^-{}_{(aq)}$$

I	0.0537	0	0
C	-x	+x	+x
E	$0.0537 - 4.79 \times 10^{-6}$	4.79×10^{-6}	4.79×10^{-6}

* Since the change is so small, you can assume the hundreds rule

Solution

* Calculate K_b

$$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$$

$$K_b = \frac{[4.79 \times 10^{-6}]^2}{[0.0537]}$$

$$K_b = 4.27 \times 10^{-10}$$

K_a, K_b, and K_w

* The relationship of and acid's K_a and it's conjugate base, K_b can be described as follows:

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$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

$$CH_3COO^- + H_2O \rightleftharpoons OH^- + CH_3COOH$$

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$$\sout{CH_3COOH} + H_2O \rightleftharpoons H_3O^+ + \sout{CH_3COO^-}$$

$$\sout{CH_3COO^-} + H_2O \rightleftharpoons OH^- + \sout{CH_3COOH}$$

$$2H_2O \rightleftharpoons OH^- + H_3O^+$$

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$$\cancel{CH_3COOH} + H_2O \rightleftharpoons H_3O^+ + \cancel{CH_3COO^-}$$

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$$2H_2O \rightleftharpoons OH^- + H_3O^+$$

$$K_aK_b = K_w$$

Example

* Calculate the K_b for the conjugate base of benzoic acid, C_6H_5COOH.

Solution

* Determine the conjugate base
  * $C_6H_5COO^-$

Solution

- Look up the K_a value of benzoic acid
  - $K_a = 6.3 \times 10^{-5}$

Solution

* Solve for K_b
  * $K_b = K_w/K_a$
  * $K_b = 1.0 \times 10^{-14} / 6.3 \times 10^{-5}$
  * $K_b = 1.6 \times 10^{-10}$

Homework

* p. 512 # 48
* p. 523 # 72
* p 526 # 83, 84