Name ______________________ Section ________ Date ________

18B Acids and Bases

Extra Practice Problems

Using Dissociation Constants

What is the difference between a strong acid and a weak acid? We say that a solution with a lower pH is more acidic than a solution with a higher pH. Since pH is a measure of hydrogen ion concentration, it should make sense that a strong acid is one that gives more hydrogen ions in solution than a weak acid. Nitric acid, HNO_3, is an example of a strong acid. It completely ionizes in aqueous solution to form hydrogen ions and nitrate ions.

$$HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$$

Hypochlorous acid, HClO, is an example of a weak acid. A weak acid ionizes only slightly in water and an equilibrium is established between the unionized form and the ionized form of the acid.

$$HClO(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$$

As in any equilibrium, we can write an expression for the equilibrium constant for this reaction. It is called the acid dissociation and has a value of 3.2×10^{-8} mol/L.

$$K_a = \frac{[H^+][ClO^-]}{[HClO]} = 3.2 \times 10^{-8}$$

We could also write an equilibrium constant expression for the strong acid. nitric acid. We normally don't so this because K_a is so large that it cannot be measured. The basicity of a solution is a measure of the hydroxide ion concentration. As with acids, the difference between a strong and a weak base also depends on the degree of ionization or reaction with water to produce hydroxide ion. A strong base, such as sodium hydroxide, NaOH, completely dissociates into a cation and the anion, the hydroxide ion.

$$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$$

A weak base only partially reacts with water producing hydroxide ion. An aqueous solution of cyanide ion, CN^-, is a weak base.

$$CN^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + HCN(aq)$$

An equilibrium constant, called the base dissociation constant, can be written for this reaction.

$$K_b = \frac{[OH^-][HCN]}{[CN^-]} = 2.0 \times 10^{-5}$$

Example A

Rank these compounds in order of increasing hydrogen ion concentration: weak acid, strong base, weak base. *18·8*

Solution The strong base will have the lowest $[H^+]$; strong base, weak base, weak acid.

You Try It

1. Rank these compounds in order of increasing hyroxide ion concentration: weak base, weak acid, strong base, strong acid. *18·8*

Your Solution

Example B

Write the expression for the acid dissociation constant of the strong acid hydrofluoric acid, HF. 18·8

Solution First write the equation.

$$HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$$

$$K_a = \frac{[H^+][F^-]}{[HF]}$$

You Try It

2. Write the expression of for the base dissociation constant for hydrazine, N_2H_4, a weak base. Hydrazine reacts with water to form the $N_2H_5^+$ ion. 18·8

Your Solution

Problems For You to Try

3. Use Table 18·5 in your text to rank these acids from weakest to strongest: $H_2C_2O_4$, HCO_3^-, $H_2PO_4^-$, HCOOH. 18·8

4. Write the equilibrium equation and the acid dissociation constant for the following weak acids: 18·8
   a. H_2S
   b. NH_4^+
   c. C_6H_5COOH

5. Match each solution with its correct description. 18·8

a. dilute, weak acid	(1) 18M $H_2SO_4(aq)$
b. dilute, strong base	(2) 0.5M $NaOH(aq)$
c. concentrated, strong acid	(3) 15M $NH_3(aq)$
d. dilute, strong acid	(4) 0.1M $HC_2H_3O_2(aq)$
e. concentrated, weak base	(5) 0.1M $HCl(aq)$

6. Write the base dissociation constant expression for the weak base analine, $C_6H_5NH_2$. 18·8

$$C_6H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_5NH_3^+(aq) + OH^-(aq)$$

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18C Acids and Bases

Extra Practice Problems

Dissociation Constants for Weak Acids and Bases

An equilibrium between the unionized and ionized forms is established when a weak acid, HA, is dissolved in water.

$$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$$

The dissociation constant expression for the weak acid, HA, takes the general form

$$K_a = \frac{[H^+] \times [A^-]}{[HA]}$$

The value of K_a can be calculated from the experimentally measured pH of a solution of known acid concentration. Conversely, if the K_a of a weak acid is known, the extent of its dissociation, and therefore, the pH of the solution can be calculated. A similar expression can be written for teh dissociation constant of a weak base, B.

$$B(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + BH^+(aq)$$

$$K_b = \frac{[OH^-] \times [BH^+]}{[B]}$$

Example A

When 0.20 mol of lactic acid, $HC_3H_5O_3$, is added to enough water to make 1.0 L of solution the equilibrium hydrogen ion concentration is $5.3 \times 10^{-3}M$. What is the K_a of lactic acid? *18·9*

Solution Write the equation for the equilibrium.

$$HC_3H_5O_3(aq) \rightleftharpoons H^+(aq) + C_3H_5O_3^-(aq)$$

Write the dissociation constant expression.

$$K_a = \frac{[H^+] \times [C_3H_5O_3^-]}{[HC_3H_5O_3]}$$

At equilibrium, $[H^+] = 5.3 \times 10^{-3}M = [C_3H_5O_3^-]$

$$[HC_3H_5O_3] = 0.20M = 5.3 \times 10^{-3}M = \sim 0.20M$$

Substitute these equilibrium concentrations into the expression for K_a.

$$K_a = \frac{(5.3 \times 10^{-3}M)(5.3 \times 10^{-3}M)}{0.20M} = 1.4 \times 10^{-4}$$

You Try It

1. A 0.10M solution of formic acid has an equilibrium $[H^+] = 4.2 \times 10^{-3}M$.

$$HCOOH(aq) \rightarrow H^+(aq) + HCOO^-(aq)$$

What is the K_a of formic acid? *18·9*

Your Solution

Example B

What is the equilibrium [H^+] of a 0.10M solution of carbonic acid, H_2CO_3. The K_a of H_2CO_3 = 4.2×10^{-7}. 18·9

Solution Write the equation for the equilibrium and the acid dissociation constant expression.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

$$K_a = \frac{[H^+] \times [HCO_3^-]}{[H_2CO_3]}$$

At equilibrium, $[H^+] = x = [HCO_3^-]$

$$[H_2CO_3] = 0.10M = x = \sim 0.10m \text{ (since } x << 0.10M)$$

Substitute into the expression for K_a and solve for x.

$$K_a = \frac{(x)\,(x)}{0.10M} = 4.2 \times 10^{-7}$$

$$x^2 = 4.2 \times 10^{-8}$$

$$x = 2.0 \times 10^{-4} = [H^+]$$

You Try It

2. The K_a of benzoic acid, C_6H_5COOH, is 6.3×10^{-5}. What is the equilibrium [H^+] in a 0.20 M solution of benzoic acid? 18·9

Your Solution

Problems For You to Try

3. A 0.10M solution of hydrocyanic acid, HCN, has an equilibrium hydrogen ion concentration of $6.3 \times 10^{-6}M$. What is the K_a of hydrocyanic acid? 18·9

4. What is the equilibrium concentration of hydrogen ion in a 0.10M solution of propanoic acid, C_2H_5COOH? The K_a of propanoic acid is 1.8×10^{-5}. 18·9

Chemistry 40S
Acid/Base Review
Answers

Review Sheet 18B

1. Strong acid, weak acid, weak base, strong base.

2. $N_2H_4(aq) + H_2O(l) <===> N_2H_5^+(aq) + OH^-(aq)$

$$K_a = \frac{[N2H5+][OH-]}{[N_2H_4]}$$

3. $HCO_3^- < H_2PO_4^- < HCOOH < H_2C_2O_4$

4. a. $K_a = \frac{[H_3O^+][HS^-]}{[H_2S]}$

   b. $K_a = \frac{[H_3O^+][NH_3]}{[NH_4^+]}$

   c. $K_a = \frac{[H_3O^+][C_6H_5COO^-]}{[C_6H_5COOH]}$

5. a. (4) b. (2) c. (1) d. (5) e. (3)

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

Review Sheet 18C

1. $K_a = 1.8 \times 10^{-4}$ M

2. $[H_3O^+] = 3.6 \times 10^{-3}$ M

3. $K_a = 4.0 \times 10^{-10}$

4. $[H_3O^+] = 1.3 \times 10^{-3}$ M