Weak Acids

A **weak acid** is an acid that does not ionize completely in water to form hydrogen (hydronium) ions. Most common acids are weak. Many naturally occurring acids are carboxylic acids, which are weak acids.

Common inorganic weak acids include hydrofluoric acid (HF), carbonic acid (H_2CO_3), hydrosulfuric acid (H_2S), and boric acid (H_3BO_3).

Percent Ionization of Weak Acids

The percent ionization of an acid, p , is defined as follows:

$$p = \frac{concentration\ of\ acid\ ionized}{concentration\ of\ acid\ solute} \times 100\%$$

The concentration of acid ionized is equal to the hydrogen ion concentration in the solution after ionization, while the concentration of acid solute is equal to the original concentration of the acid before ionization.

For the general weak acid ionization reaction,

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

$$p = \frac{[H^+]}{[HA]} \times 100\%$$

As you learned earlier, in a $0.1\ mol/L\ HCl$ solution, virtually all of the HCl molecules ionize. The concentration of hydrogen ions is, therefore, equal to the initial concentration of the acid, and $p = 100\%$.

In a $0.1\ mol/L$ solution of acetic acid (a weak acid), only 1.3% of the acetic acid molecules ionize to form hydrogen ions.

If you know the pH of a weak acid solution, it is possible to calculate the percent ionization of the acid.

Example 1
The pH of a 0.10 mol/L methanoic acid solution is 2.38. Calculate the percent ionization of methanoic acid.

Ionization Constants for Weak Acids

An equilibrium solution of a weak acid dissolved in water is just like the equilibrium systems you have studied in earlier units. Thus, the system can be represented with an equilibrium law expression and an equilibrium constant, as we have with other equilibrium systems.

The equilibrium constant for a weak acid is known as the **acid ionization constant** (K_a). For acetic acid,

$$CH_3COOH(aq) \Leftrightarrow H^+(aq) + CH_3COO^-(aq)$$

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

The percent ionization of a weak acid can be used to calculate the K_a value.

Example 2

Calculate the acid ionization constant of acetic acid if a $0.10\ mol/L$ solution at equilibrium at $25°C$ has a percent ionization of 1.3%.

The pH of Weak Acid Solutions

Since the value of K_a is constant over a range of acid concentrations, it can be used to calculate the hydrogen ion concentration and pH of weak acid solutions. We will assume all problems take place at room temperature ($25°C$) unless stated otherwise.

Example 3
Calculate the hydrogen ion concentration and the pH of a $0.10\ mol/L$ acetic acid solution.

The above calculations can also be reversed to calculate a K_a value from the pH of an acidic solution.

Example 4
You measure the pH of a $0.10\ mol/L$ hypochlorous acid ($HOCl$) solution and find it to be 4.23. What is the K_a for hypochlorous acid?

Worksheet

1. Calculate the percent ionization of propanoic acid ($HC_3H_5O_2$) if a $0.05\ mol/L$ solution has a pH of 2.78.

2. The pH of a $0.46\ mol/L$ acetic acid (CH_3COOH) solution is 2.54. Calculate the percent ionization of acetic acid.

3. What is the percent ionization of a $0.15\ mol/L\ HF$ solution whose pH is measured to be 2.00?

4. Calculate the acid ionization constant of hydrofluoric acid (HF) if a $0.10\ mol/L$ solution at equilibrium has a percent ionization of 7.8%.

5. Calculate the acid ionization constant of nitrous acid if a $0.20\ mol/L$ solution at equilibrium has a percent ionization of 5.8%.

6. Refer to the K_a values given in the Relative Strengths of Brønsted-Lowry Acids and Bases table provided.

   a) What is the hydrogen ion concentration of a $0.10\ mol/L$ solution of hydrofluoric acid?

   b) What is the hydrogen ion concentration of a $0.10\ mol/L$ solution of hydrocyanic acid?

   c) Which of the above solutions is most acidic?

7. A lab technician tests a $0.10\ mol/L$ solution of propanoic acid and finds that its hydrogen ion concentration is $1.16\times10^{-3}\ mol/L$. Calculate the percent ionization of propanoic acid in water.

8. Barbituric acid ($HC_4H_3N_2O_3$), an organic acid used to manufacture hypnotic drugs and some plastics, is a weak acid with a K_a of 9.8×10^{-5}. An industrial process requires a $0.25\ mol/L$ solution of barbituric acid. Calculate the $\left[H^+\right]$ and pH of this solution.

9. Lactic acid ($HC_3H_5O_3$) is a weak acid that gives yogurt its sour taste. Calculate the pH of a $0.025\ mol/L$ solution of lactic acid. The K_a for lactic acid is 1.4×10^{-4}.

10. Calculate the pH of $0.15\ mol/L$ methanoic acid ($HCOOH$).

11. Calculate the K_a of a $0.05\ mol/L$ solution of nicotinic acid ($HC_2H_6NO_2$) with a pH of 3.08. Nicotinic acid is one of the B vitamins, a dietary requirement.

12. A 0.25 mol/L solution of benzoic acid ($HC_7H_5O_2$), an antiseptic also used as a food preservative, has a pH of 2.40. Calculate the K_a of benzoic acid.

13. Ascorbic acid ($HC_6H_7O_6$) is a weak organic acid, also known as vitamin C. A 0.20 mol/L solution of ascorbic acid has a pH of 2.40. What is the K_a of ascorbic acid?

Answers

1. 3.3%

2. 0.63%

3. 6.7%

4. 6.6×10^{-4}

5. 7.1×10^{-4}

6. (a) $5.9\times10^{-3}\ mol/L$ (b) $7.0\times10^{-6}\ mol/L$

7. 1.16%

8. $\left[H^{+}\right]=4.9\times10^{-3}\ mol/L,\ pH=2.31$

9. 2.73

10. 2.28

11. 1.4×10^{-5}

12. 6.3×10^{-5}

13. 7.9×10^{-5}