Weak Acids and Ionization Constants
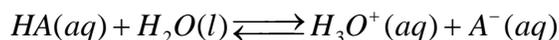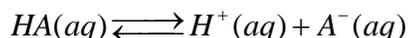
Unlike strong acids, weak acids do not ionize completely and due to that there is equilibrium between unionized acid and ionized species. Consider a weak monoprotic acid (HA), the ionization of which in water is given by

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

or more conveniently written as

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

The equilibrium expression for this ionization is

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

where K_a is known as the **acid ionization constant**, is the equilibrium constant for the ionization of an acid. The subscript a in K_a indicates an acid to distinguish acid from other solutions.

Strength of Weak Acid

At a given temperature, the strength of an acid is measured by the magnitude of K_a; larger the K_a, the stronger the acid. The following table lists few weak acids and their K_a values at 25^0C in order of decreasing acid strength.

Acid name	Acid formula	K_a
Hydrofluoric acid	HF	7.1×10^{-4}
Nitrous acid	HNO_2	4.5×10^{-4}
Acetylsalicylic acid (aspirin)	$C_9H_8O_4$	3.0×10^{-4}
Formic acid	HCOOH	1.7×10^{-4}
Ascorbic acid (vitamin C)	$C_6H_8O_6$	8.0×10^{-5}
Benzoic acid	C_6H_5COOH	6.5×10^{-5}
Acetic acid	$HC_2H_3O_2$	1.8×10^{-5}
Hydrocyanic acid	HCN	4.9×10^{-10}
Phenol	C_6H_5OH	1.3×10^{-10}

Example

Arrange the following acids in order of increasing acid strength.

(a) phenol ($K_a = 1.3 \times 10^{-10}$)
(b) nitrous acid ($K_a = 4.5 \times 10^{-4}$)
(c) acetylsalicylic acid ($K_a = 3.0 \times 10^{-4}$)
(d) acetic acid ($K_a = 1.8 \times 10^{-5}$)
(e) benzoic acid ($K_a = 6.5 \times 10^{-5}$)

Answer

Strength of an acid is determined by the magnitude of K_a; higher the K_a, stronger the acid. We arrange the above given acids from low K_a to high K_a. Thus,

phenol < acetic acid < benzoic acid < acetylsalicylic acid < nitrous acid

Example

The equilibrium reaction of a weak hydrofluoric acid (HF) is

HF(aq) → H⁺(aq) + F⁻(aq)

Which of the following statements are true or false for 1.0 M HF solution?

(a) $[H^+] < 1.0$ M
(b) $[F^-] > 1.0$ M
(c) $[H^+] = [F^-]$
(d) $[HF] = [H^+]$
(e) $[H^+] > 1.0$ M

Answer

(a) true
(b) false
(c) true
(d) false
(e) false