Lesson 8

Acids & Bases

Learning Goals

- ❑ I will be able to contrast strong and weak acids and strong and weak bases using the concept of dynamic equilibrium, and compare the strengths of acids and bases based on their ionization constants.

Arrhenius Theory of Acids and Bases (1884)

- An acid releases hydrogen ions in aqueous solution.
  e.g., $HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$

- A base releases hydroxide ions in aqueous solution.
  e.g., $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

- In an acid-base neutralization reaction, H^+ and OH^- combine to form water.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Strong acids completely ionize in water.

Examples

$$HCl(aq) \xrightarrow{100\%} H^+(aq) + Cl^-(aq)$$

$$HNO_3(aq) \xrightarrow{100\%} H^+(aq) + NO_3^-(aq)$$

Weak acids partially ionize in water; equilibrium results.

Example

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

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

K_a — acid ionization constant

higher K_a ➟ stronger acid

Strong Acid or Weak Acid?

strong acids

weak acids

IONIZATION CONSTANTS FOR ACIDS

Acid	Formula	K_a
perchloric acid	$HClO_4$	large
hydroiodic acid	HI	large
hydrobromic acid	HBr	large
hydrochloric acid	HCl	large
nitric acid	HNO_3	large
iron(III) ion	Fe^{3+}	1.5×10^{-3}
nitrous acid	HNO_2	7.2×10^{-4}
hydrofluoric acid	HF	6.6×10^{-4}
cyanic acid	HOCN	3.5×10^{-4}
methanoic acid	HCOOH	1.8×10^{-4}
chromium(III) ion	Cr^{3+}	1.0×10^{-4}
benzoic acid	C_6H_5COOH	6.3×10^{-5}
ethanoic acid	CH_3COOH	1.8×10^{-5}

Hydronium Ions, H_3O^+

- In aqueous solutions, hydrogen ions combine with water molecules to form hydronium ions.

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

$$HF(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + F^-(aq)$$

- For simplicity, chemist often use H^+ in place of H_3O^+.

STRONG AND WEAK **BASES**

Strong bases are ionic hydroxides that completely dissociate in water.

Examples

$$NaOH(aq) \xrightarrow{100\%} Na^{+}(aq) + OH^{-}(aq)$$

$$Ca(OH)_2(aq) \xrightarrow{100\%} Ca^{2+}(aq) + 2\ OH^{-}(aq)$$

Weak bases react incompletely with water to produce hydroxide ions; equilibrium is reached.

Example

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

$$K_b = \frac{[NH_4^+(aq)]\,[OH^-(aq)]}{[NH_3(aq)]}$$

K_b — base ionization constant

higher K_b ➟ stronger base

Ionization Constants for Weak Bases

Base	Formula	K_b
dimethylamine	$(CH_3)_2NH$	9.6×10^{-4}
methylamine	CH_3NH_2	4.4×10^{-4}
ethylamine	$C_2H_5NH_2$	4.3×10^{-4}
trimethylamine	$(CH_3)_3N$	7.4×10^{-5}
ammonia	NH_3	1.8×10^{-5}
hydrazine	N_2H_4	9.6×10^{-7}
hydroxylamine	NH_2OH	6.6×10^{-9}
pyridine	C_5H_5N	1.5×10^{-9}
aniline	$C_6H_5NH_2$	4.1×10^{-10}

Autoionization of Water

- Water partially ionizes producing hydrogen ions and hydroxide ions.

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

$$K_w = [H^+(aq)]\,[OH^-(aq)]$$

$$= 1.0 \times 10^{-14} \quad (\text{at } 25\,^\circ C)$$

K_w — ionization constant for water

Success Criteria

- I can contrast strong and weak acids and strong and weak bases using the concept of dynamic equilibrium, and compare the strengths of acids and bases based on their ionization constants.