

Acids And Bases

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Introduction:

- The concept of acids and bases is fundamental to chemistry.
- Over time, several definitions have been proposed to explain acid-base behavior under different conditions (aqueous, gaseous, non-aqueous, etc.).

Three Major Theories:

Theory	Acid Definition	Base Definition	Scope
Arrhenius	Produces H^+ in water	Produces OH^- in water	Limited to aqueous solutions
Brønsted-Lowry	Proton donor	Proton acceptor	Broader (not limited to water)
Lewis	Electron pair acceptor	Electron pair donor	Most general; includes non-protonic reactions

- We'll explain Brønsted-Lowry in detail in the next topic, so let's focus here on an overview and understanding of acid/base strength, behavior, and properties.

General Characteristics

1. Acids

- Taste sour (in edible substances).
- Turn blue litmus paper red.
- React with metals to release hydrogen gas.
- React with bases in neutralization reactions to form salts and water.
- Have $pH < 7$ in aqueous solutions.

2. Bases

- Taste bitter and feel slippery (soapy).
- Turn red litmus paper blue.
- React with acids to neutralize them.
- Often contain hydroxide ions (OH^-) or accept protons.
- Have $pH > 7$ in aqueous solutions.

Acid and Base Strength

A. Strong Acids:

- Completely dissociate in water.
- **Examples:** HCl, HBr, HI, HNO₃, HClO₄, H₂SO₄ (first proton)

B. Weak Acids:

- Partially dissociate.
- **Example:** CH₃COOH (acetic acid), HF, H₂CO₃

C. Strong Bases:

- Fully dissociate into OH⁻.
- **Examples:** NaOH, KOH, Ba(OH)₂

D. Weak Bases:

- Partially accept protons (often produce OH⁻ indirectly).
- **Examples:** NH₃, CH₃NH₂

Quantifying Strength

A. For Acids:

- **K_a** = Acid dissociation constant
 - $HA \rightleftharpoons H^+ + A^-$
 - $K_a = \frac{[H^+][A^-]}{[HA]}$
- **pK_a = -log(K_a)**
 - Lower pK_a = Stronger acid
 - Higher pK_a = Weaker acid

B. For Bases:

- **K_b** = Base dissociation constant
 - $B + H_2O \rightleftharpoons BH^+ + OH^-$
 - $K_b = \frac{[BH^+][OH^-]}{[B]}$
- **pK_b = -log(K_b)**
 - Lower pK_b = Stronger base
- **Relation:** pK_a + pK_b = 14 (at 25°C)

Acid-Base Reactions:

- **Neutralization:**
 - Acid + Base → Salt + Water
 - Example: HCl + NaOH → NaCl + H₂O
- **Acid-Base Equilibrium:**

- Favor the formation of the weaker acid-base pair.
- Proton transfers are governed by relative strengths (ΔpK_a).

Conjugate Acid-Base Pairs:

- Every acid has a conjugate base (what remains after it donates a proton).
- Every base has a conjugate acid (what forms after it accepts a proton).
- Example:
 - Acid: $\text{HCl} \rightarrow$ Conjugate base: Cl^-
 - Base: $\text{NH}_3 \rightarrow$ Conjugate acid: NH_4^+
- Stronger acid $\rightarrow$ weaker conjugate base, and vice versa.

Amphoteric Substances:

- Compounds that can act as both acid and base, depending on the environment.
- Example: Water (H_2O)
 - Acts as base with HCl (accepts H^+)
 - Acts as acid with NH_3 (donates H^+)

Acid-Base Properties in Non-Aqueous Solvents:

- Acid-base behavior can differ outside water.
- In liquid ammonia, for example:
 - NH_4^+ is an acid
 - NH_2^- is a base
- This shows the importance of solvent system in defining acid-base strength and reactions.

Leveling Effect:

- In water, strong acids like HCl , HNO_3 , and H_2SO_4 all appear to have the same strength because they completely dissociate, forming H_3O^+ .
- Water levels the strength of all strong acids to that of H_3O^+ .
- The same applies to strong bases and OH^- in water.

Importance in Chemistry:

- Determines solubility, reactivity, and equilibrium in chemical systems.
- Central to titrations, buffer solutions, reaction mechanisms, and biological functions (e.g., enzyme activity).

Brønsted–Lowry Theory (Proton Transfer Theory)

Definition:

- **Brønsted–Lowry Acid:** A substance that donates a proton (H^+).
- **Brønsted–Lowry Base:** A substance that accepts a proton (H^+).
- This theory extends beyond aqueous solutions and is more general than Arrhenius theory.

Key Concepts:

A. Acid-Base Reaction as Proton Transfer:

➤ General form:



- HA: acid (proton donor)
- B: base (proton acceptor)
- A^- : conjugate base
- HB^+ : conjugate acid

➤ Example:



- HCl is the Brønsted acid
- H_2O is the Brønsted base
- Cl^- is the conjugate base
- H_3O^+ is the conjugate acid

B. Conjugate Acid-Base Pairs:

- Always exist in **pairs**.
- **Acid** $\leftrightarrow$ **Conjugate base** (loses a proton)
- **Base** $\leftrightarrow$ **Conjugate acid** (gains a proton)
- Example:



- NH_3 is base, NH_4^+ is its conjugate acid
- H_2O is acid, OH^- is its conjugate base

Strength Relationship:

- Strong acid $\rightarrow$ Weak conjugate base
- Weak acid $\rightarrow$ Strong conjugate base
- **Example:**
 - HCl (strong acid) $\rightleftharpoons$ Cl^- (very weak base)



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