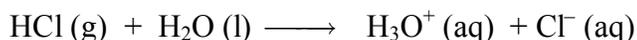


ACIDS & BASES

- Many common substances in our daily lives are **acids and bases**. **Oranges, lemons and vinegar** are examples of **acids**. In addition, our stomachs contain acids that help digest foods. **Antacid** tablets taken for heartburn and **ammonia** cleaning solutions are examples of **bases**.
- General properties associated with acids include the following:
 - sour taste
 - change color of litmus from blue to red
 - react with metals to produce H₂ gas
 - react with bases to produce salt and water
- General properties associated with bases include the following:
 - bitter taste
 - slippery soapy feeling
 - change color of litmus from red to blue
 - react with acids to produce salt and water
- The most common definition of acids and bases was formulated by the Swedish chemist Svante **Arrhenius** in 1884.
- According to the **Arrhenius** definition,
 - **Acids are substances that produce hydronium ion (H₃O⁺) in aqueous solution**



Commonly written as

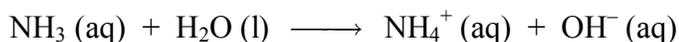


Polar Covalent

- **Bases are substances that produce hydroxide ion (OH⁻) in aqueous solution**

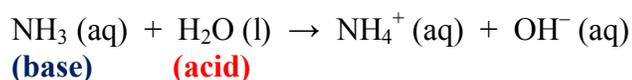
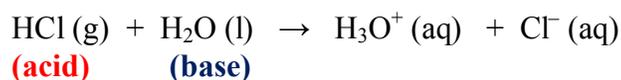


Ionic compound

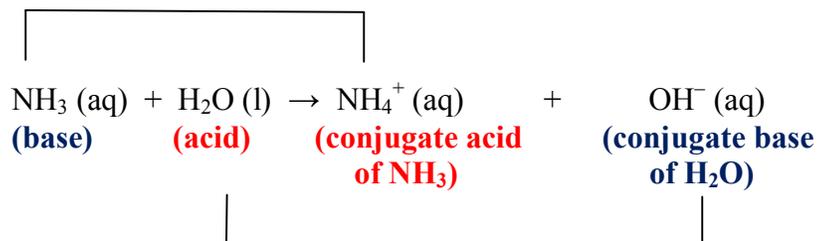
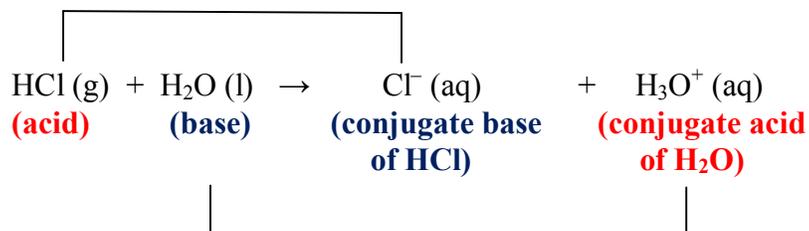


BRØNSTED-LOWRY ACIDS & BASES

- The **Arrhenius** definition of acids and bases is **limited to aqueous solutions**.
- A broader definition of acids and bases was developed by **Brønsted and Lowry** in the early 20th century.
- According to **Brønsted-Lowry** definition, an **acid** is a **proton donor**, and a **base** is a **proton acceptor**.

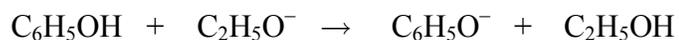
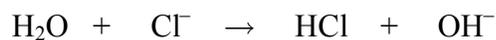


- A substance that can act as a **Brønsted-Lowry acid and base** (such as **water**) is called **amphiprotic**.
- In Brønsted-Lowry definition, any pair of molecules or ions that can be **interconverted by transfer of a proton** is called **conjugate acid-base pair**.



BRØNSTED-LOWRY ACIDS & BASES**Examples:**

1. Identify the conjugate acid-base pairs for each reaction shown below:



2. Write the formula for the conjugate acid for each base shown:



3. Write the formula for the conjugate base for each acid shown:

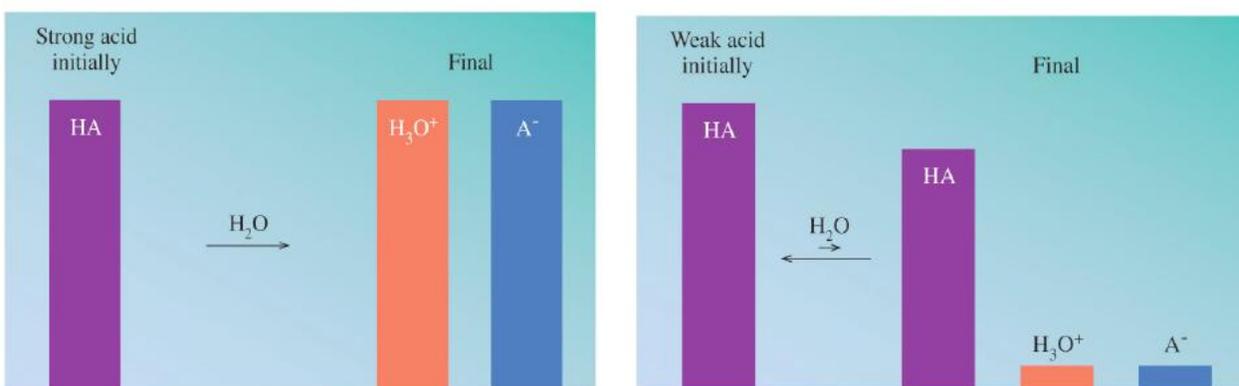
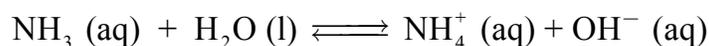


ACID & BASE STRENGTH

- According to the **Arrhenius** definition, the **strength** of acids and bases is based on the amount of their **ionization** in water.
- **Strong acids and bases are those that ionize completely in water.**
- Strong acids and bases are **strong electrolytes**.



- **Weak acids and bases are those that ionize partially in water, and are therefore written as reversible reactions (indicated by \rightleftharpoons).**
- Weak acids and bases are **weak electrolytes**.



Ionization of Strong vs. Weak acids

ACID & BASE STRENGTH

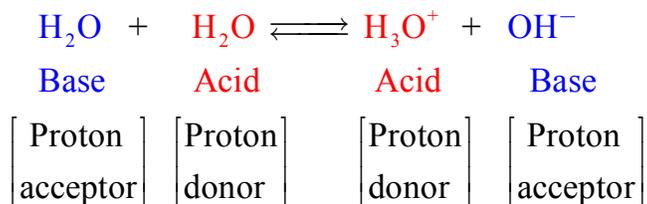
- Listed below are the formulas and names of common acids and bases, and comparison of their characteristics.

COMMON STRONG ACIDS & BASES			
HCl	Hydrochloric acid	LiOH	Lithium hydroxide
HBr	Hydrobromic acid	NaOH	Sodium hydroxide
HI	Hydroiodic acid	KOH	Potassium hydroxide
HNO ₃	Nitric acid	Ca(OH) ₂	Calcium hydroxide
H ₂ SO ₄	Sulfuric acid	Ba(OH) ₂	Barium hydroxide
COMMON WEAK ACIDS & BASES			
HC ₂ H ₃ O ₂	Acetic acid	NH ₃	Ammonia
H ₂ CO ₃	Carbonic acid	CO(NH ₂) ₂	Urea
H ₃ PO ₄	Phosphoric acid		
HF	Hydrofluoric acid		
HCN	Hydrocyanic acid		
H ₂ S	Hydrosulfuric acid		

Characteristic	Acids	Bases
Reaction: Arrhenius	Produce H ⁺	Produce OH ⁻
Reaction: Brønsted–Lowry	Donate H ⁺	Accept H ⁺
Electrolytes	Yes	Yes
Taste	Sour	Bitter, chalky
Feel	May sting	Slippery
Litmus	Red	Blue
Phenolphthalein	Colorless	Pink
Neutralization	Neutralize bases	Neutralize acids

IONIZATION OF WATER

- As noted previously, **water** can act both as an **acid and a base**.
- In pure water, one **water** molecule **donates a proton** to another water molecule to produce **ions**.



- In pure water, the **transfer of protons** between water molecules produces **equal numbers of H₃O⁺ and OH⁻ ions**. However, the number of ions produced in pure water is very small, as indicated below:

$$\text{Pure water} \quad [\text{H}_3\text{O}^+] = [\text{OH}^-] = 1.0 \times 10^{-7} \text{ M}$$

- When the **concentrations of H₃O⁺ and OH⁻ are multiplied** together, the **ion-product constant (K_w)** is formed.

$$\begin{aligned}
 K_w &= [\text{H}_3\text{O}^+] \times [\text{OH}^-] \\
 &= (1.0 \times 10^{-7} \text{ M}) \times (1.0 \times 10^{-7} \text{ M}) = 1.0 \times 10^{-14}
 \end{aligned}$$

- All aqueous solutions have **H₃O⁺ and OH⁻ ions**. An **increase in the concentration** of one of the ions will cause an equilibrium shift that causes a **decrease in the other one**.

ACIDIC & BASIC SOLUTIONS

- When $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ are equal in a solution, it is **neutral**.
- When $[\text{H}_3\text{O}^+]$ is **greater** than $[\text{OH}^-]$ in a solution, it is **acidic**.

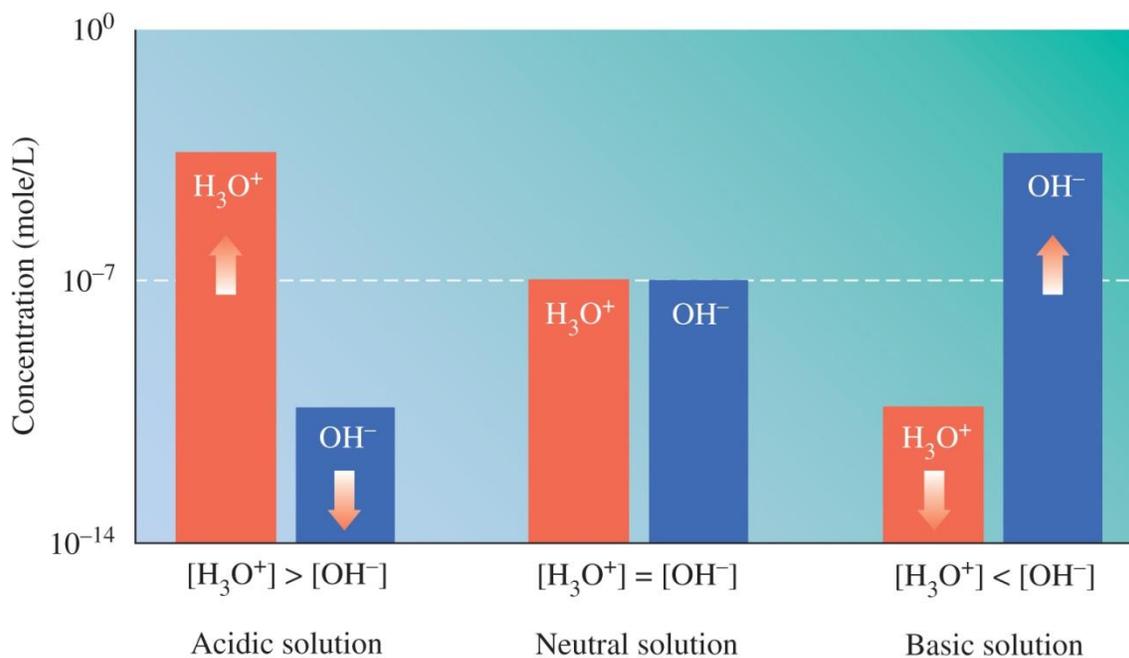
For example, if $[\text{H}_3\text{O}^+]$ is 1.0×10^{-4} M, then $[\text{OH}^-]$ would be 1.0×10^{-10} M.

$$[\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]} = \frac{1.0 \times 10^{-14}}{1.0 \times 10^{-4}} = 1.0 \times 10^{-10} \text{ M}$$

- When $[\text{OH}^-]$ is **greater** than $[\text{H}_3\text{O}^+]$ in a solution, it is **basic**.

For example, if $[\text{OH}^-]$ is 1.0×10^{-6} M, then $[\text{H}_3\text{O}^+]$ would be 1.0×10^{-8} M.

$$[\text{H}_3\text{O}^+] = \frac{K_w}{[\text{OH}^-]} = \frac{1.0 \times 10^{-14}}{1.0 \times 10^{-6}} = 1.0 \times 10^{-8} \text{ M}$$



ACIDIC & BASIC SOLUTIONS**Examples:**

1. Calculate the $[\text{OH}^-]$ in a solution with $[\text{H}_3\text{O}^+] = 2.3 \times 10^{-4} \text{ M}$. Classify the solution as acid or basic.

$$[\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]} =$$

2. Calculate the $[\text{H}_3\text{O}^+]$ in a solution with $[\text{OH}^-] = 3.8 \times 10^{-6} \text{ M}$. Classify the solution as acid or basic.

$$[\text{H}_3\text{O}^+] = \frac{K_w}{[\text{OH}^-]} =$$

3. Calculate the $[\text{OH}^-]$ in a solution with $[\text{H}_3\text{O}^+] = 5.8 \times 10^{-8} \text{ M}$. Classify the solution as acid or basic.

4. Calculate the $[\text{H}_3\text{O}^+]$ in a solution with $[\text{OH}^-] = 1.3 \times 10^{-2} \text{ M}$. Classify the solution as acid or basic.

THE pH SCALE

- The **acidity** of a solution is commonly measured on a **pH scale**.

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

- The **pH scale** ranges from **0-14**, where **acidic** solutions are **less than 7** and **basic** solutions are **greater than 7**.

Acidic solutions	pH < 7	$[\text{H}_3\text{O}^+] > 1.0 \times 10^{-7}$
Neutral solutions	pH = 7	$[\text{H}_3\text{O}^+] = 1.0 \times 10^{-7}$
Basic solutions	pH > 7	$[\text{H}_3\text{O}^+] < 1.0 \times 10^{-7}$

Examples:

- The $[\text{H}_3\text{O}^+]$ of a liquid detergent is 1.4×10^{-9} M. Calculate its pH.

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log [1.4 \times 10^{-9}] = -(-8.85) = 8.85$$

- The pH of black coffee is 5.3. Calculate its $[\text{H}_3\text{O}^+]$.

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH}) = 10^{-\text{pH}} = 10^{-5.3} = 5 \times 10^{-6}$$

- The $[\text{H}_3\text{O}^+]$ of a solution is 3.5×10^{-3} M. Calculate its pH.

- The pH of tomato juice is 4.1. Calculate its $[\text{H}_3\text{O}^+]$.

- The $[\text{OH}^-]$ of a cleaning solution is 1.0×10^{-5} M. What is the pH of this solution?

$$[\text{H}_3\text{O}^+] = \quad \quad \quad \text{pH} =$$

- The pH of a solution is 11.50. Calculate the $[\text{H}_3\text{O}^+]$ for this solution.