

Chapter 14

Aqueous Equilibria: Acids and Bases

Acid – Base Theories

There are **three** acid/base theories used to define acids and bases:

- 1.
- 2.
- 3.

Arrhenius Theory

Most specific of the three acid-base theories.

Arrhenius Acid -

Arrhenius Base -

- * Only defines acids and bases with water as a solvent
- * H^+ must be present to define a substance as an acid
- * OH^- must be present to define a substance as base
- * Arrhenius theory does not explain the basicity of ammonia
- * To define ammonia as a base – we need **new definitions** of acids and bases

Lewis Theory

Most general of the three acid-base theories.

Lewis Acid-

Lewis Base-

Examples: Identify the Lewis acid and Lewis base in the following reactions.
What type of bond is formed in the product of a Lewis acid-base reaction?

1. $\text{BCl}_3 + \text{NH}_3 \rightarrow \text{Cl}_3\text{BNH}_3$
2. $2 \text{Cl}^- + \text{BeCl}_2 \rightarrow \text{BeCl}_4^{2-}$
3. $6 \text{H}_2\text{O} + \text{Al}^{3+} \rightarrow \text{Al}(\text{H}_2\text{O})_6^{3+}$
4. $\text{H}^+ + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+$

NOTE: Lewis acid-base reactions are VERY important in organic chemistry!!

Bronsted-Lowry Theory

Bronsted-Lowry Acid-

Bronsted-Lowry Base-

- * In Bronsted-Lowry reaction, the proton is transferred from the _____ to the _____!
- * Drawback to Bronsted-Lowry Theory..... _____ must be present to define a substance as an acid.

In the following acid-base reactions identify the acid and base

1. $\text{HPO}_4^{2-} + \text{HSO}_4^- \rightarrow \text{SO}_4^{2-} + \text{H}_2\text{PO}_4^-$
2. $\text{HCO}_3^- + \text{H}_2\text{O} \rightarrow \text{CO}_3^{2-} + \text{H}_3\text{O}^+$
3. $\text{HSO}_3^- + \text{HS}^- \rightarrow \text{H}_2\text{S} + \text{SO}_3^{2-}$
4. $\text{NH}_3 + \text{CH}_3\text{COOH} \rightarrow \text{NH}_4^+ + \text{CH}_3\text{COO}^-$
5. $\text{H}_2\text{CO}_3 + \text{CO}_3^{2-} \rightarrow 2 \text{HCO}_3^-$

Conjugate Acid-Base Pairs

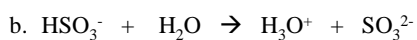
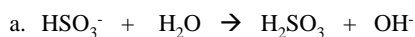
Two substances with chemical formulas that differ from each other by ONE proton (H^+).

As an example...consider the equilibrium of acetic acid established in aqueous solution. Write the acetic acid equilibrium and identify the two conjugate acid/base pairs.

Acetic Acid Eq:

Examples:

1. Identify the conjugate acid/base pairs for the reactions below.



2. Give the formulas for the conjugate acid and conjugate base of each of the following.



Autoionization or Dissociation of water

- * Water is amphoteric – it can act both as an acid or base
- * Water will act as an acid if a stronger base is present
- * Water will act as a base if a stronger acid is present
- * Water can self-ionize i.e. undergo an acid base reaction with itself

Write the reaction for autoionization/dissociation of water:

where K_w = ion-product constant or dissociation constant of water

If $K_w = 1.0 \times 10^{-14}$ at 25 °C, what are $[H_3O^+]$ and $[OH^-]$ in pure water at 25°C?

Basicity/Acidity of Solutions

A **NEUTRAL** solution is one in which.... a.
b.

An **ACIDIC** solution is one in which.... a.
b.

A **BASIC** solution is one in which.... a.
b.

How are the concentrations of OH^- and H_3O^+ related?

Sample Questions

1. At 25°C, the $[\text{H}_3\text{O}^+]$ in a sample of lemon juice is 3.0×10^{-3} M. Is the lemon juice acidic, basic, or neutral? Calculate the concentration of OH^- ions.
2. At 25°C, the $[\text{OH}^-]$ in a sample of seawater is 5.0×10^{-6} M. Is the seawater acidic, basic, or neutral? Calculate $[\text{H}_3\text{O}^+]$ in the seawater.
3. Which is more acidic, a beer with $[\text{H}_3\text{O}^+] = 3.16 \times 10^{-5}$ M or a wine with $[\text{OH}^-] = 2.00 \times 10^{-11}$ M?

pH Scale

Provides a more convenient (non-exponential) way of expressing $[\text{H}_3\text{O}^+]$!

pH = ??

- Examples:**
- A. A soft drink has $[\text{H}_3\text{O}^+] = 2.0 \times 10^{-5}$ M. What is the pH of this soft drink? Is the soft drink acidic basic or neutral?
- B. A neutral solution has $[\text{OH}^-] = [\text{H}_3\text{O}^+] = 1.0 \times 10^{-7}$. What is the pH of this solution?

An acidic solution is one in which... a.

A basic solution is one in which.... a.

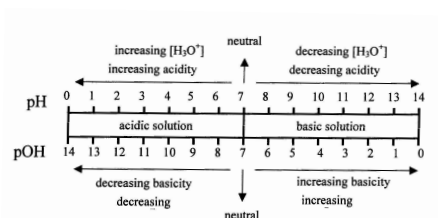
A neutral solution is one in which..... a.

Relationship between pOH and pH

pOH can be defined in the same way as pH. Use the ion-product expression for water to derive the relationship between pH and pOH.

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

The relationship between pH and pOH is:



Sample questions

- Calculate the pH of an aqueous ammonia solution that has $[\text{OH}^-] = 1.9 \times 10^{-3} \text{ M}$.
- Acid rain is a matter of serious concern because most species of fish die in waters having a pH lower than 4.5 – 5.0. Calculate the $[\text{H}_3\text{O}^+]$ in a lake that has a pH of 4.5.
- Calculate the concentrations of $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ in each of the following solutions:
 - human blood (pH = 7.40) ($[\text{H}_3\text{O}^+] = 4.0 \times 10^{-8} \text{ M}$; $[\text{OH}^-] = 2.5 \times 10^{-7} \text{ M}$)
 - a cola beverage (pH = 2.8) ($[\text{H}_3\text{O}^+] = 2 \times 10^{-3} \text{ M}$; $[\text{OH}^-] = 6 \times 10^{-12} \text{ M}$)
- An aqueous solution has a pOH of 8.9. Is this solution acidic, basic, or neutral? Calculate the $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ in this solution.
- Which of the solutions in i-iv is MOST basic? A solution with.....
 - pH = 6.5
 - pOH = 5.5
 - $[\text{H}_3\text{O}^+] = 1 \times 10^{-9} \text{ M}$
 - $[\text{OH}^-] = 1 \times 10^{-9} \text{ M}$

pH Calculations of Strong Acids and Strong Bases

Addition of strong acid/strong base to water, suppresses the autoionization of water!

1. Calculate the pH, pOH, $[\text{H}_3\text{O}^+]$, and $[\text{OH}^-]$ of 0.25 M HClO_4 .
2. Calculate the pH, pOH, $[\text{H}_3\text{O}^+]$, and $[\text{OH}^-]$ of 0.0050 M $\text{Ba}(\text{OH})_2$.
3. Calculate the pH of a 1.0×10^{-9} M HCl solution.
4. Calculate the pH of a 5.0×10^{-10} M $\text{Ca}(\text{OH})_2$ solution.
5. Calculate the pH of the solutions formed by dissolving 1.0 g of each of the following substances in 500. mL of solution.
A. HBr B. Na_2O C. SrO