2.4.3: Overview of the Acid-Base Properties of Salt

Some salts, such as ammonium bicarbonate (NH$_4$HCO$_3$), contain cations and anions that can both undergo hydrolysis.

Learning Objectives

• Predict the pH of a solution of a salt containing cations and anions, both of which participate in hydrolysis.

Key Points

• Basic salts result from the neutralization of a strong base with a weak acid.
• Acid salts result from the neutralization of a strong acid with a weak base.
• For salts in which both cation and anion are capable of hydrolysis, compare $K_a$ and $K_b$ values to determine the solution's resulting pH.

Key Terms

• **neutralization reaction**: a reaction between an acid and a base in which water and a salt are formed
• **hydrolysis**: a reaction with water in which chemical bonds break
• **salt**: in acid-base chemistry, one of the products in a neutralization reaction
Summary of Acidic and Basic Salts

As we have discussed, salts can form acidic or basic solutions if their cations and/or anions are hydrolyzable (able to react in water). Basic salts form from the neutralization of a strong base and a weak acid; for instance, the reaction of sodium hydroxide (a strong base) with acetic acid (a weak acid) will yield water and sodium acetate. Sodium acetate is a basic salt; the acetate ion is capable of deprotonating water, thereby raising the solution’s pH.

Acid salts are the converse of basic salts; they are formed in the neutralization reaction between a strong acid and a weak base. The conjugate acid of the weak base makes the salt acidic. For instance, in the reaction of hydrochloric acid (a strong acid) with ammonia (a weak base), water is formed, along with ammonium chloride. The ammonium ion contains a hydrolyzable proton, which makes it an acid salt.

Salts in Which Both Ions Hydrolyze

The following is a more complicated scenario in which a salt contains a cation and an anion, both of which are capable of participating in hydrolysis. A good example of such a salt is ammonium bicarbonate, NH₄HCO₃; like all ammonium salts, it is highly soluble, and its dissociation reaction in water is as follows:

\[
\text{NH}_4\text{CO}_3(s) \rightarrow \text{NH}_4^+(aq) + \text{HCO}_3^-(aq)
\]

However, as we have already discussed, the ammonium ion acts as a weak acid in solution, while the bicarbonate ion acts as a weak base. The reactions are as follows:

\[
\begin{align*}
\text{NH}_4^+(aq) + \text{H}_2\text{O}(l) &\rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{NH}_3(aq) \\
K_a &= 5.6 \times 10^{-10}
\end{align*}
\]

\[
\begin{align*}
\text{HCO}_3^-(aq) + \text{H}_2\text{O}(l) &\rightleftharpoons \text{H}_2\text{CO}_3(aq) + \text{OH}^-(aq) \\
K_b &= 2.4 \times 10^{-8}
\end{align*}
\]

Because both ions can hydrolyze, will a solution of ammonium bicarbonate be acidic or basic? We can determine the answer by comparing \( K_a \) and \( K_b \) values for each ion. In this case, the value of \( K_b \) for bicarbonate is greater than the value of \( K_a \) for ammonium. Therefore, bicarbonate is a slightly more alkaline than ammonium is acidic, and a solution of ammonium bicarbonate in pure water will be slightly basic (pH > 7.0). In summary, when a salt contains two ions that hydrolyze, compare their \( K_a \) and \( K_b \) values:

- If \( K_a > K_b \), the solution will be slightly acidic.
- If \( K_b > K_a \), the solution will be slightly basic.

Hydrolysis of salts: This video examines the hydrolysis of an acid salt, a basic salt, and a salt in which both ions hydrolyze.