Salt Solutions

Salts are ionic solids composed of a positive and a negative ion arranged in a crystalline lattice. When they dissolve in water, they dissociate into individual ions that may or may not affect the pH of the solution.

As an example, consider potassium fluoride — the salt of a strong base (KOH) and a weak acid (HF). When potassium fluoride dissolves in water, it dissociates into potassium ions and fluoride ions.

$$KF(s) \rightarrow K^+(aq) + F^-(aq)$$

Some of the fluoride ions react with water molecules to establish the following equilibrium.

$$F^-(aq) + H_2O(l) \Leftrightarrow HF(aq) + OH^-(aq)$$

Since this reaction increases the OH^- ion concentration, the resulting solution will be basic.

Next, consider ammonium chloride — the salt of a weak base (NH_3) and a strong acid (HCl). When dissolved in water, the salt dissociates into ammonium ions and chloride ions.

$$NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$$

The ammonium ions then react with water molecules to establish the following equilibrium.

$$NH_4^+(aq) + H_2O(l) \Leftrightarrow NH_3(aq) + H_3O^+(aq)$$

Since this reaction increases the H_3O^+ ion concentration, the resulting solution will be acidic.

In general, since salts contain two different ions, the pH of an aqueous salt solution may be affected by the positive ion, the negative ion, or both. The reaction of an ion with water to produce an acidic or basic solution is called **hydrolysis**.

Salts That Form Neutral Solutions

In general, salts that consist of positive ions from strong bases (e.g. Na^+ and K^+) and negative ions from strong acids (e.g. Cl^- and NO_3^-) have no effect on the pH of an aqueous solution. Some examples are shown in the table below.

Salt	Positive Ion From Strong Base	Negative Ion From Strong Acid
$NaCl$	$NaOH$	HCl
KCl	KOH	HCl
NaI	$NaOH$	HI
$NaNO_3$	$NaOH$	HNO_3

Another way of looking at this is, if a salt is the result of a reaction between a strong acid and a strong base, that salt will produce a neutral salt solution. For example,

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Since $NaCl$ is formed by the reaction between a strong acid and a strong base, a solution of this salt will be neutral.

Salts That Form Acidic Solutions

In general, positive ions that are conjugate acids of weak bases act as weak acids, and thus lower the pH of a solution. Some examples are shown in the table below.

Salt	Positive Ion of Weak Base	
NH_4Cl	NH_4^+	NH_3
N_2H_5Br	$N_2H_5^+$	N_2H_4

Another way of looking at this is, if a salt is the result of a reaction between a strong acid and a weak base, that salt will produce an acidic salt solution. For example,

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

This solution is acidic because the ammonium ion (NH_4^+) acts as an acid when it reacts with water.

$$NH_4^+(aq) + H_2O(l) \rightarrow H_3O^+(aq) + NH_3(aq) \qquad pH < 7$$

Salts That Form Basic Solutions

In general, negative ions that are conjugate bases of weak acids act as weak bases, and thus raise the pH of a solution.

Another way of looking at this is, if a salt is the result of a reaction between a weak acid and a strong base, that salt will produce a basic salt solution. For example,

$$CH_3COOH(aq) + NaOH(aq) \rightarrow NaCH_3COO(aq) + H_2O(l)$$

This solution is basic because the acetate ion (CH_3COO^-) acts as a base when it reacts with water.

$$CH_3COO^-(aq) + H_2O(l) \Leftrightarrow CH_3COOH(aq) + OH^-(aq) \qquad pH > 7$$

Worksheet

1. Write equations for the dissociation and hydrolysis reactions that occur when the following salts are dissolved in water. Classify each solution as acidic, basic, or neutral.

   a) ammonium nitrate

   b) rubidium acetate

   c) potassium sulfate

   d) calcium carbonate

   e) sodium carbonate

   f) ammonium bromide