**Introduction**

Salts can be neutral, acidic or basic. The ions of the salt are the conjugate base and conjugate acid of the acid and base that formed the salt, and the question is, do they react with water to form their parent base and acid?

Let's look at the generic reaction

\[
\text{酸} \quad \text{HA(aq)} + \text{碱} \quad \text{B(aq)} \rightleftharpoons \text{酸的共轭酸} \quad \text{BH}^+(aq) + \text{碱的共轭酸} \quad \text{A}^-(aq)
\]

So the salt \((BH^+)(A^-)\) is made of the conjugate acid of B (ie., \(BH^+\)), and the conjugate base of A (ie., \(A^-\)). Noting the stronger the acid or base, the weaker it's conjugate (base or acid). Using Acid Ionization Constants (\(K_a\), Table 16.3.1) and Base Ionization Constants (\(K_b\), Table 16.3.2), one can calculate the conjugate acid ionization constant (\(K_a'\)) and the conjugate base ionization constant (\(K_b'\)) using the relationships \(K_aK_b'=K_w\) and \(K_bK_a'=K_w\)

**Conjugate Base Ionization Constant**

Using the Acid Ionization Constants from Table

\[
K_b' = \frac{10^{-14}}{K_a}
\]

Exercise \(\PageIndex{1}\)

What is the ionization constant for acetate?

**Answer**

Acetate is the conjugate base of acetic acid, and from table 16.3.1 \(K_a=1.75\times 10^{-5}\).

\[
K_b'(C_2H_3O_2^-) =\frac{10^{-14}}{1.75\times 10^{-5}}=5.71\times 10^{-10}
\]

**Conjugate Acid Ionization Constant**

\[
K_a' = \frac{10^{-14}}{K_b}
\]

Exercise \(\PageIndex{2}\)

What is the ionization constant for ammonium?

**Answer**

Ammonium is the conjugate acid of ammonia, and from Table 16.3.2 \(K_b=1.8\times 10^{-5}\).

\[
K_a'(NH_4^+) =\frac{10^{-14}}{1.8\times 10^{-5}}=5.6\times 10^{-10}
\]
Four Types of Salt Solutions

Since acids and bases can be weak or strong there are four types of salts that can result, and these will result in neutral, acidic or basic solutions. That is, the acid can be Strong (SA) or Weak (WA) and the base can be Strong (SB) or Weak (WB).

1. Salt of Strong Acid and Strong Base
2. Salt of Strong Acid and Weak Base
3. Salt of Weak Acid and Strong Base
4. Salt of Weak Acid and Weak Base

Neutral Salt (Strong Acid/Strong Base)

Review Acid Base Conjugate pairs figure 16.3.1 for the relationship between conjugate pair strengths.

These are neutral since the anion and cation are both weak as they are the conjugates of a strong acid and strong base. That is, they are stable in water and do not react with water to form the original acid or base.

Example NaCl, which is formed by the reaction of the strong acid HCl and the strong base NaOH.

\[\text{NaCl(aq)} \rightarrow \text{Na}^+(aq)+\text{Cl}^-(aq)\]
\[\text{Na}^+(aq) + \text{H}_2\text{O(l)} \rightarrow \text{no reaction}\]
\[\text{Cl}^-(aq) + \text{H}_2\text{O(l)} \rightarrow \text{no reaction}\]

so it is neutral
Acidic Salt (Strong Acid/Weak Base)

These are acidic since the cation is the conjugate acid of a weak base, and the weaker the base, the stronger the acid.

Example: Ammonium Chloride which is formed from the reaction of HCl (strong acid) and ammonia (weak base).

\[
\textcolor{red}{NH_4}Cl(aq) \rightarrow \textcolor{red}{NH_4^+}(aq) + Cl^-(aq)
\]

\[Cl^-(aq) + H_2O(l) \rightarrow \text{no reaction}\]

\[
\textcolor{red}{NH_4^+(aq)+ H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)}
\]

so it is acidic, and

\[
[K_{a}^{'}(NH_4^+) = \frac{10^{-14}}{1.8 \times 10^{-5}}=5.6 \times 10^{-10}]\]
Basic Salt (Weak Acid/Strong Base)

These are basic because the anion is the conjugate base of a weak acid.

Example: Sodium fluoride is formed from the reaction of acetic acid (weak acid) and sodium hydroxide (strong base).

$$\text{Na}^+(\text{aq}) + \text{F}^-(\text{aq}) \rightarrow \text{NaF}(\text{aq})$$

$$\text{Na}^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{no reaction}$$

$$\text{F}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HF}(\text{aq}) + \text{OH}^-(\text{aq})$$

$$K_b^{'}(\text{F}^-) = \frac{10^{-14}}{6.3 \times 10^{-4}} = 1.6 \times 10^{-11}$$
Variable A/B Salt (Weak Acid/Weak Base)

These may be acidic or basic as both the cation and the anion interact with water. If the acid that makes the salt is stronger then it is acidic, because it's conjugate base is weaker. And if the base that makes the salt is stronger, it is basic, because its conjugate is weaker.

\[
\textcolor{red}{NH_4}\textcolor{blue}{F}(aq) \rightarrow \textcolor{red}{NH_4^+}(aq) +\textcolor{blue}{F^-}(aq)\]
\[
\textcolor{blue}{F^-}(aq)+ H_2O(l) \rightleftharpoons HF(aq) + OH^-(aq)\]
\[
\textcolor{red}{NH_4^+}(aq)+ H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)\]

Noting: \(K_b(NH_3)= 1.8\times 10^{-5}\ \ K_a(HF)=6.3\times 10^{-4}\)

So \(K_a(HF) > K_b(NH_3)\)

and students may think it is acidic because the acid that made the salt is stronger then the base, but it is acidic because the base's conjugate (an acid) is stronger than the acid's conjugate (a base).

\[
\frac{K_a(NH_3)}{(NH_4^+)}=\frac{10^{-14}}{1.8\times 10^{-5}}=5.6\times 10^{-10}\]
\[
\frac{K_b(F^-)}{(F^-)}=\frac{10^{-14}}{6.3\times 10^{-4}}=1.6\times 10^{-11}\]
That is, $K'_a (\text{NH}_4^+) > K'_b (\text{F}^-)$

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