Unit 7, Lesson 08: The pH of Salt Solutions

Salts are produced when acids and bases react in neutralization reactions.

When soluble salts dissolve in water, they completely dissociate into their ions. If the parent acid or base of the ions are weak acids or weak bases, these ions will react with water and produce $H_3O^{1+}{}_{(aq)}$ or OH^{1-} (aq) ions. Because the ions are reacting with or "splitting water" apart to form hydronium or hydroxide ions, the ions are said to "hydrolyze" (split water apart). The resulting salt solutions will NOT necessarily be neutral. They can be acidic, basic or neutral depending on the salt. The effects of both ions in the salt must be considered in order to determine the pH of a salt solution.

1. Salts of strong acids and strong bases: eg. NaBr

a) Look at the positive ion, Na^{1+}

- the parent base of Na^{1+} is NaOH, which is a very strong base
- Because NaOH is a very strong base, Na^{1+} is a very weak acid. It is too weak to react with water to produce H_3O^+
- Therefore, Na^{1+} ions do not react with water (do not hydrolyze) and the presence of Na^{1+} ions does not affect the pH of a solution

b) Look at the negative ion, Br^{1-}

- the parent acid of Br^{1-} is HBr, which is a very strong acid
- Because HBr is a very strong acid, Br^{1-} is a very weak base. It is too weak to react with water to produce OH^{1-}
- Therefore, Br^{1-} ions do not react with water (do not hydrolyze) and the presence of Br^{1-} ions does not affect the pH of a solution

Because neither Na^{1+} nor Br^{1-} react significantly with water, the pH of a solution of NaBr is neutral.

2. Salts of strong acids and weak bases: eg. NH_4NO_3

a) Look at the positive ion, NH_4^{1+}

- the parent base of NH_4^{1+} is NH_3, which is a weak base (a solution of NH_3 is also written NH_4OH)
- Because NH_3 is a weak base, NH_4^{1+} is a relatively strong acid. It will react with water to produce H_3O^+

$$NH_4^{1+}{}_{(aq)} + H_2O_{(l)} \rightarrow NH_{3\,(aq)} + H_3O^{1+}{}_{(aq)}$$

- Therefore, NH_4^{1+} ions will react with water (hydrolyze) to form H_3O^{1+} which will make the solution acidic

b) Look at the negative ion, NO_3^{1-}

- the parent acid of NO_3^{1-} is HNO_3, which is a very strong acid
- Because HNO_3 is a very strong acid, NO_3^{1-} is a very weak base. It is too weak to react with water to produce OH^{1-}
- Therefore, NO_3^{1-} ions do not react with water (do not hydrolyze) and the presence of NO_3^{1-} ions does not affect the pH of a solution

Because of the presence of the acidic NH_4^{1+} ion with the neutral NO_3^{1-} ion, the pH of a solution of NH_4NO_3 will be acidic.

3. Salts of weak acids and strong bases: eg. $Mg(CH_3COO)_2$

a) Look at the positive ion, Mg^{2+}

- the parent base of Mg^{2+} is $Mg(OH)_2$, which is a very strong base
- Because $Mg(OH)_2$ is a very strong base, Mg^{2+} is a very weak acid. It is too weak to react with water to produce H_3O^+
- Therefore, Mg^{2+} ions do not react with water (do not hydrolyze) and the presence of Mg^{2+} ions does not affect the pH of a solution

b) Look at the negative ion, CH_3COO^{1-}

- the parent acid of CH_3COO^{1-} is CH_3COOH, which is a weak acid.
- Because CH_3COOH is a weak acid, CH_3COO^{1-} is a relatively strong base. It is strong enough to react with water to produce OH-

$$CH_3COO^{1-}{}_{(aq)} + H_2O_{(l)} \rightarrow CH_3COOH_{(aq)} + OH^{1-}{}_{(aq)}$$

- Therefore, CH_3COO^{1-} ions will react with water (hydrolyze) to form OH^- which will make the solution basic

Because of the presence of the neutral Mg^{2+} ion with the basic CH_3COO^{1-} ion, the pH of a solution of $Mg(CH_3COO)_2$ will be basic.

4. Salts of weak acids and weak bases: eg. NH_4ClO_2

(This material is not testable. It will be dealt with at university but it follows the same pattern we have been discussing.)

In this situation, both of the ions will hydrolyze (react with) water. The pH of the final solution will depend on the relative strengths of the ions.

- If the k_a of the weak acid is stronger than the k_b of the weak base, then the final solution will be acidic.
- If the k_b of the weak base is stronger than the k_a of the weak acid, then the final solution will be basic.

The parent base of NH_4^{1+} is the weak base, NH3 (also written NH_4OH). Therefore, NH_4^{1+} is a strong enough acid to react with water (hydrolyzes) according to the reaction:

$$NH_4^{1+}{}_{(aq)} + H_2O_{(l)} \rightarrow NH_{3\,(aq)} + H_3O^{1+}{}_{(aq)} \qquad k_a = (1.0 \times 10^{-14} / k_b \text{ of } NH_3) = 5.6 \times 10^{-10}$$

The parent acid of ClO_2^{1-} is the weak acid, $HClO_2$. Therefore, ClO_2^{1-} is a strong enough base to react with water (hydrolyzes) according to the reaction:

$$ClO_2^{1-}{}_{(aq)} + H_2O_{(l)} \rightarrow HClO_{2\,(aq)} + OH^{1-}{}_{(aq)} \qquad k_b = (1.0 \times 10^{-14} / k_a \text{ of } HClO_2) = 9.1 \times 10^{-13}$$

Because the k_a of NH_4^{1+} is greater than the k_b of ClO_2^{1-}, the pH of the salt solution will be acidic.