SAN JACINTO COLLEGE

STUDENT SUCCESS CENTER

Acid-Base Properties of Salt Solutions

Acid-base Strength

Acid and base solutions can be ranked by the extent they ionize in an aqueous solution. The reaction of an acid with water is given by the following general expression:

$$\mathrm{HA(aq) + H_2)\ (l) \leftrightarrow H_3O^+(aq) + A^-(aq)}$$

Water is the base that reacts with the acid HA, A^- is the conjugate base of the acid HA, and the hydronium ion is the conjugate acid of water. A strong acid yields 100% (or very nearly so) of H_3O^+ and A^- when the acid ionizes in water. As for weaker acids, their relative strength can be found by measuring the equilibrium constant of their ionization reaction. Stronger acids yield a higher concentration of the hydronium ion. A higher acid-ionization constant (K_a) also indicates a stronger acid property. The reported concentrations are the equilibrium concentration in the reaction.

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

Relative base strength can be identified in the same manner. A base reaction in water and base-ionization constant equation are given by the following expressions:

$$B(aq) + H_2O(l) \leftrightarrow HB^+(aq) + OH^-(aq)$$

$$K_b = \frac{[HB^+][OH^-]}{[B]}$$

Water acts as an acid that reacts with the base, HB^+ is the conjugate acid of the base B, and the hydroxide ion is the conjugate base of water.

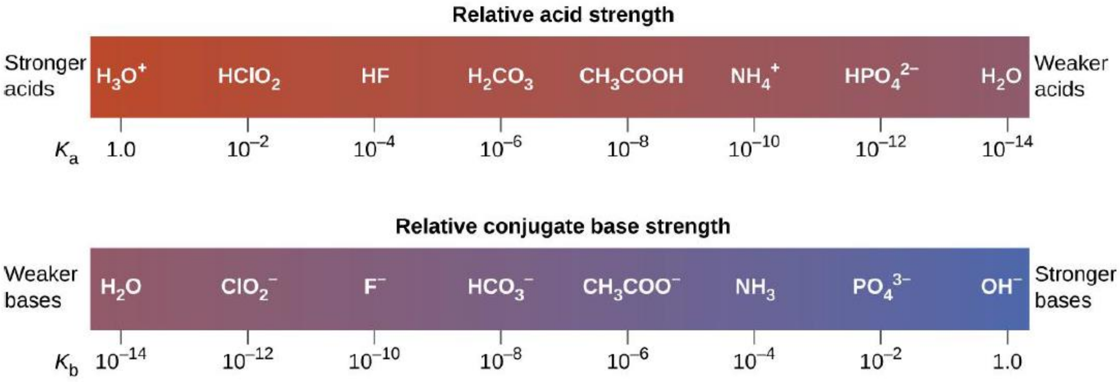
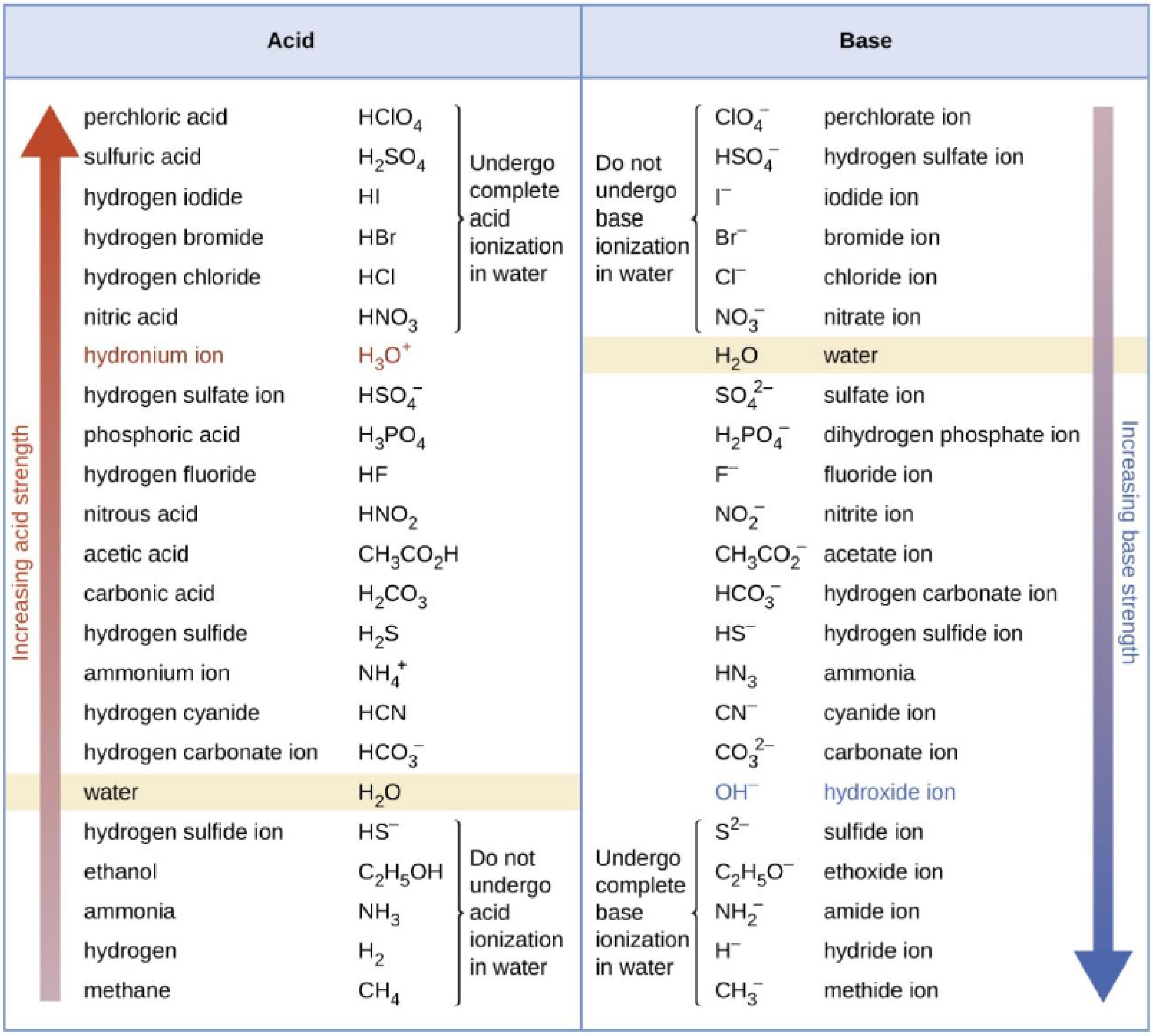


Figure 1 Relative strength of conjugate acid-base pairs *[4]*

A strong base yields 100% (or very nearly so) of OH^- and HB^+ when it reacts with water. Similar to acids K_a, K_b indicates the relative strength of bases as well. Stronger bases produce a higher concentration of hydroxide ion. Figure 1 and Figure 2 indicate the relative strength of conjugate acid-base pairs [1], [2].



Acid			Base		
perchloric acid	$HClO_4$	Undergo complete acid ionization in water	Do not undergo base ionization in water	ClO_4^-	perchlorate ion
sulfuric acid	H_2SO_4			HSO_4^-	hydrogen sulfate ion
hydrogen iodide	HI			I^-	iodide ion
hydrogen bromide	HBr			Br^-	bromide ion
hydrogen chloride	HCl			Cl^-	chloride ion
nitric acid	HNO_3			NO_3^-	nitrate ion
hydronium ion	H_3O^+			H_2O	water
hydrogen sulfate ion	HSO_4^-			SO_4^{2-}	sulfate ion
phosphoric acid	H_3PO_4			$H_2PO_4^-$	dihydrogen phosphate ion
hydrogen fluoride	HF			F^-	fluoride ion
nitrous acid	HNO_2			NO_2^-	nitrite ion
acetic acid	CH_3CO_2H			$CH_3CO_2^-$	acetate ion
carbonic acid	H_2CO_3			HCO_3^-	hydrogen carbonate ion
hydrogen sulfide	H_2S			HS^-	hydrogen sulfide ion
ammonium ion	NH_4^+			HN_3	ammonia
hydrogen cyanide	HCN			CN^-	cyanide ion
hydrogen carbonate ion	HCO_3^-			CO_3^{2-}	carbonate ion
water	H_2O			OH^-	hydroxide ion
hydrogen sulfide ion	HS^-	Do not undergo acid ionization in water	Undergo complete base ionization in water	S^{2-}	sulfide ion
ethanol	C_2H_5OH			$C_2H_5O^-$	ethoxide ion
ammonia	NH_3			NH_2^-	amide ion
hydrogen	H_2			H^-	hydride ion
methane	CH_4			CH_3^-	methide ion

Figure 2 Relative strengths of conjugate acid-base pairs. *[4]*

Hydrolysis

Hydrolysis is defined as the dissolution of salts in water to produce H_3O^- or OH^-. Hydrolysis solutions normally show acidic or basic natures, considering the strength of ions hydrolyzing in water. Different structures of salts will produce various pH ranges in an aqueous solution. Salt is defined as the formed ionic compound derived from a neutralization reaction between an acid and a base. Therefore, the comprising cations and anions are respectively the conjugate acids and conjugate bases of the used acid and base compounds.

Depending on the relative strength of the salt ions, basic and acidic salts will form when dissolved in an aqueous solution [3].

Basic Salts

Basic salts are formed from the neutralization reaction between a strong acid and a weak base. In basic salts, the anion is the conjugate base of a weak acid. In general, anions A^- can be considered the conjugate base of the acid HA. Depending on the strength of the corresponding acid:

- A^-, the conjugate base of a *weak* acid, acts as a weak base.
- A^-, the conjugate base of a *strong* acid, acts as a pH-neutral.

For example, the F- anion is the conjugate base of HF, a weak acid; therefore, it produces a basic solution when dissolved in water.

On the other hand, the Cl- anion is the conjugate base of HCl, a strong acid; thus, it shows neither acidic nor basic nature and acts as a pH-neutral agent in water.

Acidic Salts

Since the cation acts as weak, a salt with an anion of a strong acid and a cation of a weak base produces an acidic solution with a pH less than 7. In this case, the anion becomes the spectator ion, while the weak acid dissociates in water and yields H_3O^+ ions. Therefore,

- HB^+, the conjugate acid of a *weak* base, acts as a weak acid.
- HB^+, the conjugate acid of a *strong* base, acts as a pH-neutral.

For example, NH_4Cl yields an acidic solution since the NH_4^+, the cation of base NH_3, reacts with water and forms a weak acid, while the Cl^-, the anion of strong acid HCL, forms a spectator ion.

Neutral Salts

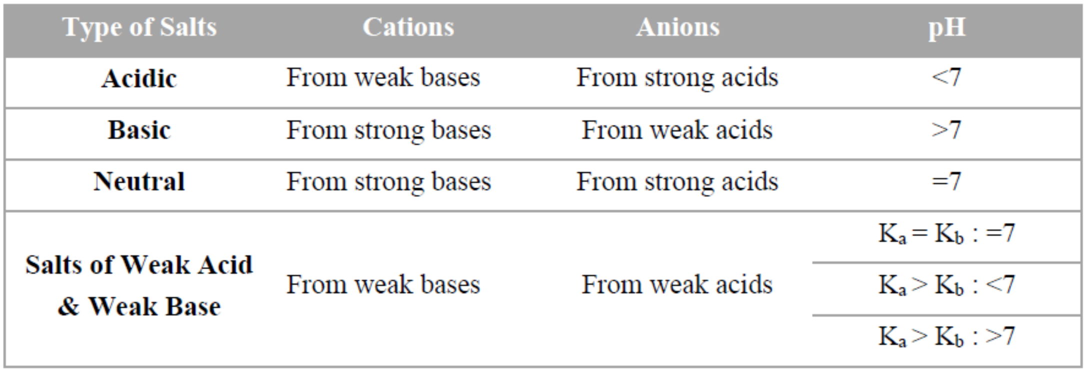
Salts that are from strong acids and strong bases normally do not hydrolyze and no reaction occurs between the ions and water; therefore, the solution remains neutral with a pH=7.

For example, salts consisting of halides (except F^-) and alkaline metals dissociate in water, but do not affect since the anion does not attract H_3O^- and the cation does not change the H_3O^+.

The anions of strong acids are the halide ions (except F^-) and those of strong oxoacids like NO_3^- and ClO_4^-. Group 1A (1) and Ca^{2+}, Sr^{2+}, and Ba^{2+} from group 2A (2) consist of the cations of the strong bases.

Salts of Weak Acids and Weak Bases

In this case, both the anion and the cation react with water; therefore, we can predict whether the solution will be basic, acidic, or neutral by comparing the K_a value for the acidic ion with the K_b value for the basic ion. Table 1 shows a summary of acid-base properties of the salts [1], [3].



Type of Salts	Cations	Anions	pH
Acidic	From weak bases	From strong acids	<7
Basic	From strong bases	From weak acids	>7
Neutral	From strong bases	From strong acids	=7
Salts of Weak Acid & Weak Base	From weak bases	From weak acids	$K_a = K_b$: =7
			$K_a > K_b$: <7
			$K_a > K_b$: >7

Table 1 Summary of acid base properties of *salts*

Methodology

We need to look at the salt and ask these questions:

- Which acid and which base reacted to form it?
- Is the acid strong or weak?
- Is the base strong or weak?

Note that the strong acid or base dissociates completely and the resulting ion is a spectator. The remaining ion of the salt reacts with water.

- If you predict a basic solution, the hydrolysis reaction will be:

$$B(aq) + H_2O(l) \leftrightarrow HB^+(aq) + OH^-(aq)$$

- If you predict an acidic solution, the hydrolysis reaction will be:

$$HA(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + A^-(aq)$$

References

[1] M. S. Silderberg, Principles of General Chemistry, New York: McGraw-Hill, 2007.

[2] N. J. Tro, Chemistry: A Molecular Approach, Upper Saddle River, NJ: Pearson, 2014.

[3] “Libretexts. ‘7.8: Acid-Base Properties of Salts.’,” 21 July 2016. [Online]. Available: https://chem.libretexts.org/LibreTexts/University_of_California%2C_Santa_Cruz/UCSC%3A_Chem_1B-AL_(Mednick)/Map%3A_Chemistry_(Zumdahl_and_Decoste)/7%3A_Acids_and_Bases/7.08_Acid-Base_Properties_of_Salts. [Accessed 18 2 2018].

[4] “Acid and Base Strength,” 13 Feb 2017. [Online]. Available: https://chem.libretexts.org/LibreTexts/University_of_California%2C_Santa_Cruz/UCSC%3A_Chem_1B-AL_(Mednick)/Map%3A_Chemistry_(Zumdahl_and_Decoste)/7%3A_Acids_and_Bases/7.08_Acid-Base_Properties_of_Salts. [Accessed 18 2 2018].

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