What is Kb for $H_2BO_3^-$?

$H_2BO_3^- + H_2O \rightleftharpoons H_3BO_3 + OH^-$

Base

A

$K_b = \frac{K_w}{K_{a(H_3BO_3)}} = \frac{1 \times 10^{-14}}{7.3 \times 10^{-10}}$

$K_b = 1.4 \times 10^{-5}$

Salt Hydrolysis

Hydrolysis = reaction between water and the cation or anion (or both) contained in a salt to produce an acidic or basic solution

- spectator ions - do not participate in the reaction
- when considering hydrolysis, spectator ions do not hydrolyze

Spectator cations (+)

- alkali metals (group 1)
- alkaline earth metals (group 2)

Spectator anions (-)

- conjugate bases of strong acids (ClO_4-, I-, Br-, Cl- and NO_3-)
- HSO_4- is not a spectator as it is a weak acid

- when an ion hydrolyzes, it is merely acting as a Brønsted-Lowry acid or base with water

a) **Anionic (-) Hydrolysis**

> if the anion of the salt hydrolyzes, it acts as a base to accept a proton and produce $OH^-(aq)$

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

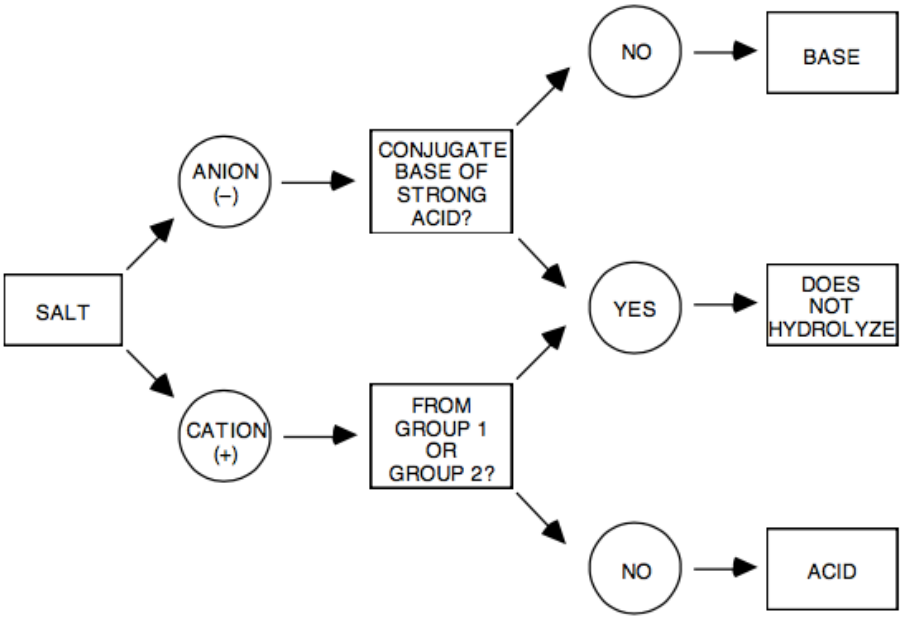
b) **Cationic (+) Hydrolysis**

> if the cation of the salt hydrolyzes, it acts as a acid & donates a proton to produce $H_3O^+(aq)$

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

Anions (-) hydrolyze to give basic solutions
Cations (+) hydrolyze to give acidic solutions

- procedure for determining the behaviour of a salt in water:
  - > determine the ions produced when the salt dissociates
  - > omit spectator ions
  - > remaining ions will behave as acids (cations) or bases (anions)



Predicting salt hydrolysis:

Predict whether each of the following salts hydrolyzes in water and write the hydrolysis equation for the reactions:

a) NaCl b) NH_4Cl c) KF d) NH_4NO_2 e) $NaHCO_3$

a) $NaCl \rightarrow Na^+ + Cl^-$

Na^+: Spectator Cl^-: Spectator

NEUTRAL

b) $NH_4Cl \rightarrow NH_4^+ + Cl^-$

NH_4^+: cation → Acid Cl^-: Spectator

c) $KF \rightarrow K^+ + F^-$

F^-: anion

Basic

d) $NH_4NO_2 \rightarrow NH_4^+ + NO_2^-$

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

Acid

$K_a = 5.6 \times 10^{-10}$

$NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$

base

$K_b = \frac{K_w}{K_a(HNO_2)} = \frac{1 \times 10^{-14}}{4.6 \times 10^{-4}} = 2.2 \times 10^{-11}$

$K_a > K_b \Rightarrow$ ACIDIC

e) $NaHCO_3 \rightarrow Na^+ + HCO_3^-$

Na^+: Spectator

$HCO_3^- + H_2O \rightleftharpoons CO_3^{2+} + H_3O^+$

Acid

$K_a = 5.6 \times 10^{-11}$

$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$

Base

$K_b = \frac{K_w}{K_a(H_2CO_3)} = \frac{1 \times 10^{-14}}{4.3 \times 10^{-7}} = 2.3 \times 10^{-8}$

$K_b > K_a$ = basic

- some metal ions (those with 3+ or 2+ and very small ionic radii such as Fe^{3+}, Cr^{3+} and Al^{3+}) will react with water to form acidic solutions

  > the hydrolysis reactions for these can be found on the table of Relative Strengths of Acids

$$Al(H_2O)_6^{3+}(aq) + H_2O \rightleftarrows [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+$$

- metal ions from Group 1 and 2 (except Be^{2+}) do not hydrolyze
- there are certain oxygen-containing compounds **(oxides)** that also react with water to produce acidic or basic solutions

1. metal oxides

> when a metal oxide is added to water, there is an initial dissociation of ions:

$$Na_2O(s) \rightarrow 2Na^+(aq) + O^{2-}(aq)$$

$$CaO(s) \rightarrow Ca^{2+}(aq) + O^{2-}(aq)$$

> the metal ions are spectators and the oxide ion (O^{2-}) is a strong base

> hydrolysis of the oxide ion is given by:

$$O^{2-}(aq) + H_2O(l) \rightarrow 2OH^-(aq)$$

> since both the $Na^+(aq)$ and the $OH^-(aq)$ ions are present in solution, we can write the hydrolysis of $Na_2O(s)$ and $CaO(s)$ as

$$Na_2O(s) + H_2O \rightarrow 2NaOH(aq)$$

$$CaO(s) + H_2O \rightarrow Ca(OH)_2(aq)$$

2. Nonmetal oxides

- when a non-metal oxide reacts with water, the water bonds to the existing oxide molecule to produce an **acidic** solution
- these are referred to as **acid anhydrides**

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

$$N_2O_5(g) + H_2O(l) \rightarrow H_2NO_3(aq)$$

$$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$$

Metal oxides produce **basic** solutions when dissolved in water.
Nonmetal oxides produce **acidic** solutions when dissolved in water.

3. Metalloid oxides

- many metals and most metalloids form oxides or hydroxides that can react as either acids or bases
- common elements that form **amphoteric** oxides:

Zn, Al, Pb, Be, Fe, Co, Sn

In acids: $ZnO + 2H^+ \rightarrow Zn^{2+} + H_2O$

In bases: $ZnO + H_2O + 2OH^- \rightarrow [Zn(OH)_4]^{2-}$

amphoteric = substances that react as acids or bases

Metal oxides produce **basic** solutions when dissolved in water.

Nonmetal oxides produce **acidic** solutions when dissolved in water.

Metalloid oxides are **amphoteric**.