ACID-BASE EQUILIBRIUM
2: ACID BASE SALTS

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SALT SOLUTIONS

Salts of neutralization reactions can be acidic or basic depending on the strength of acid and base. This is because the conjugate acids and bases can have higher strength which can then react with water to form hydronium or hydroxide ions.

- Strong acid (HCl) + strong base (NaOH) $\longrightarrow$ gives neutral salts (NaCl).
  - Conjugate acid: $Na^+ + H_2O \longrightarrow$ No Reaction (NR)
  - Conjugate base: $Cl^- + H_2O \longrightarrow$ NR
- Strong acid (HCl) + weak base (NH_3) $\longrightarrow$ gives weak conjugate acids (NH_4^+), so weak acidic solutions in water.
  - Conjugate acid: $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$
- Weak acid (HF) + strong base (NaOH) $\longrightarrow$ gives weak conjugate bases (F^-), so weak basic solutions in water.
  - Conjugate base: $F^- + H_2O \rightleftharpoons HF + OH^-$

SALT SOLUTIONS

Here are the guidelines again.

In General….	Example
A cation that makes solution acidic: • Conjugate acid of weak base • A small highly charged metal	 NH_4^+, $CH_3NH_3^+$ Al^{3+}, Cr^{3+}, Fe^{3+}, Bi^{3+}
An anion that makes a solution basic is: • Conjugate base of a weak acid	 CN^-, NO_2^-, CH_3COO^-
A cation that does not affect pH of solution: • Group I ion	 Li^+, Na^+
An anion that will not affect pH of a solution: • The conjugate base of a strong acid	 Cl^-, NO_3^-, ClO_4^-

IDENTIFYING ACIDIC/BASIC SALTS

To identify the acidic or basic nature of the salt,

- break it down into its anion and cation;
- then see what it is a conjugate acid or base of, and
- then determine the acidity/basicity of the salt.

Examples:

NaBr: Na^+ is the conjugate acid of NaOH, a strong base.
Br^- is the conjugate base of HBr, a strong acid. (SA+SB = neutral salt)

$NaC_2H_3O_2$: Na^+ is the conjugate acid of NaOH, a strong base.
$C_2H_3O_2^-$ is the conjugate base of $HC_2H_3O_2$, a weak acid.
(WA + SB = basic salt; because anion is good conjugate base coming from a weak acid)

NH_4Cl: NH_4^+ is the conjugate acid of NH_3, a weak base.
Cl^- is the conjugate base of HCl, a strong acid.
(SA + WB = acidic salt; because the cation is a good conjugate acid coming from a weak base)

EXAMPLE 1: IDENTIFYING ACID/BASE SALTS

Ammonium nitrate, NH_4NO_3, is administered as an intravenous solution to patients whose blood pH has deviated from the normal value of 7.40. Would this substance be used for acidosis (blood pH < 7.40) or alkalosis (blood pH > 7.40)?

Answer:

NH_4^+ is the conjugate acid of a NH_3, a weak base. NH_4^+ is acidic.

NO_3^- is the conjugate base of HNO_3, a strong acid. NO_3^- is neutral.

NH_4NO_3 is acidic, so it could be used for alkalosis

DETERMINING ACID/BASE SALT BY K_a AND K_b

If $K_a > K_b$, the solution is acidic.

If $K_a < K_b$, the solution is basic.

If $K_a = K_b$, the solution is neutral.

$$\boxed{K_w = K_a \times K_b}$$

Determine whether NH_4F will give an acidic or basic solution. Use K_a and K_b from the data tables.

Answer:

Use K_b for NH_3

$$\text{For } NH_4{}^+\text{:}\ K_a = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$$

Use K_a for HF

$$\text{For } F^-\text{:}\ K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{6.8 \times 10^{-4}} = 1.5 \times 10^{-11}$$

$$K_a \text{ for } NH_4{}^+ > K_b \text{ for } F^-$$

NH_4F is acidic.

EXAMPLE 2: pH OF A SALT SOLUTION -1

Determine the pH of a 0.25 *M* solution of pyridinium nitrate ($C_5H_5NHNO_3$) at 25 °C. [Pyridinium nitrate dissociates in water to give pyridinium ions ($C_5H_5NH^+$) ($K_b = 1.7 \times 10^{-9}$)*, and nitrate ions (NO_3^-).]

*NOTE: If K_b is given then salt is of a weak base therefore is acidic in water.

Answer:

$\boxed{K_w = K_a \times K_b}$

$$K_a = \frac{K_w}{K_b} = \frac{1.00 \text{ x } 10^{-14}}{1.7 \text{ x } 10^{-9}} = 5.9 \text{ x } 10^{-6}$$

$$C_5H_5NH^+_{(aq)} + H_2O_{(l)} \rightleftharpoons C_5H_5N_{(aq)} + H_3O^+_{(aq)}$$

Initial	0.25 M		0	0
Change	$-x$		$+x$	$+x$
Eq.	$0.25 - x$		x	x

Note: K_a is 10^{-6} so it is safe to ignore x.

$$K_a = \frac{[C_5H_6N][H_3O^+]}{[C_5H_6NH^+]}$$

$$K_a = \frac{x^2}{(0.25 - x)} \cong \frac{x^2}{(0.25)} = 5.9 \times 10^{-6}$$

$$x = \sqrt{(5.9 \text{ x } 10^{-6})(0.25)} = 1.2 \times 10^{-3} M = [H_3O^+]$$

$$pH = -\log(1.2 \times 10^{-3} \text{ M}) = \boxed{2.92}$$

EXAMPLE 3: pH OF A SALT SOLUTION - 2

Household bleach is a 5% solution of sodium hypochlorite, NaClO. This corresponds to a molar concentration of about 0.70 *M* NaClO. What is the $[OH^-]$ and the pH of the solution? HClO, $K_a = 3.5 \times 10^{-8}$.*

*__NOTE__: If K_a is given then salt is of a weak acid and is basic in water.

Answer: $K_b = 2.9 \times 10^{-7}$ (Using the K_w expression)

$$ClO^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HClO_{(aq)} + OH^-_{(aq)}$$

Initial	0.70 M		0	0
Change	$-x$		$+x$	$+x$
Eq.	$0.70 - x$		x	x

$$K_b = \frac{[HClO]\,[OH^-]}{[ClO^-]}$$

$$2.9 \times 10^{-7} = \frac{x^2}{0.70}$$

$$x^2 = 2.0 \times 10^{-7}$$

$$x = 4.5 \times 10^{-4}\ \text{M}$$

$$[OH^-] = x = 4.5 \times 10^{-4}\ \text{M}$$

$$\text{pH} = 14.00 = \text{pOH} = 14.00 - \log[OH^-]$$
$$\text{pH} = 14.00 - \log(4.5 \times 10^{-4})$$

$$\text{pH} = 14.00 - 3.35 = \boxed{10.65}$$

KEY CONCEPTS

- Identify acidic and basic salts
- Calculate pH of acidic and basic salt solutions