SCH 4U
ACID-BASE PROPERTIES OF SALT SOLUTIONS

SALT HYDROLYSIS

Salts are ionic, this means that they dissociate 100% in solution to give free aqueous ions.

$$NaCl \longrightarrow Na^+ + Cl^-$$

When both ions come from strong acids and bases they have no interactions with water, however if the ions come from weak acids and bases then they interact with water establishing equilibria.

EXAMPLE: *sodium ethanoate solution*
sodium ethanoate is 100% dissociated into ions when mixed with water:
$CH_3COONa \longrightarrow CH_3COO^-_{(aq)} + Na^+_{(aq)}$

Sodium ions are from a strong base (NaOH) and do not interact with water molecules.
However, ethanoate ions <u>do</u> interact with water:

$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$

We know that the equilibrium lies to the side of the ethanoic acid (to the right). As $[OH^-]$ increases, the pH rises.
A solution of sodium ethanoate has a pH greater than 7. We say that it is basic by hydrolysis.

EXAMPLE: *Ammonium chloride solution*
Ammonium chloride dissociates 100% into ions in solution
$NH_4Cl \longrightarrow NH_4^+ + Cl^-$

Ammonium ions interact with water (equilibrium lies to the right)
$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

This increases the concentration of hydrogen ions, increasing the acidity of the solution (decrease pH).
We say that a solution of ammonium chloride is acidic by hydrolysis.

General rules

- *When the negative ion is from a weak acid then the salt is basic by hydrolysis*
- *When the positive ion is from a weak base then the salt is acidic by hydrolysis*
- *If the salt is formed from a strong acid and strong base then it is neutral*

For each salt, predict whether it will hydrolyze, and if so, determine if the aqueous solution will be acidic, basic or neutral.

① $KCl \rightarrow K^+ + Cl^-$

- Look at each ion for possible hydrolysis
- ***Cation*** rule:
  - Group 1 ions and Group 2 ions (except Be^{2+}) ***do not*** hydrolyze. They are cations of strong bases.
  - All other cations hydrolyze.

- ***Anion*** rule:
  - Cl^- is a conjugate base of a **strong** acid HCl and does not hydrolyze
  - Similarly, the acids of Br^-, I^-, ClO_4^-, SO_4^{2-} and NO_3^- are all strong
  - All other anions hydrolyze.
- For the given salt KCl, since neither ion hydrolyzes, the only reaction is ...
  $H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$

② $NH_4NO_3 \rightarrow NH_4^+ + NO_3^-$

- NH_4^+ will hydrolyze
- NO_3^- will not hydrolyze since it is the conjugate base of a strong acid
  $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$; the solution will be acidic.

③ $NaHCO_3 \rightarrow Na^+ + HCO_3^-$

- Na^+ will not hydrolyze
- HCO_3^- is the conjugate base of a weak acid therefore it will hydrolyze
  $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$; the solution will be basic.
- ALSO CONSIDER: HCO_3^- is amphiprotic
  - $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$ $K_b = 2.3 \times 10^{-8}$
  - $HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+$ $K_a = 4.7 \times 10^{-11}$
  - Since $K_b > K_a$ the solution will be basic

④ $NH_4NO_2 \rightarrow NH_4^+ + NO_2^-$

- Both ions will hydrolyze.
- Examine hydrolysis reactions and K_a and K_b values
  - $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ $K_a = 5.7 \times 10^{-10}$
  - $NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$ $K_b = 2.0 \times 10^{-11}$
  - Since $K_a > K_b$, the NH_4^+ is a stronger acid than the NO_2^- is a base, therefore the solution will be acidic.