Chapter 8.6
Acid-Base Properties of Salt

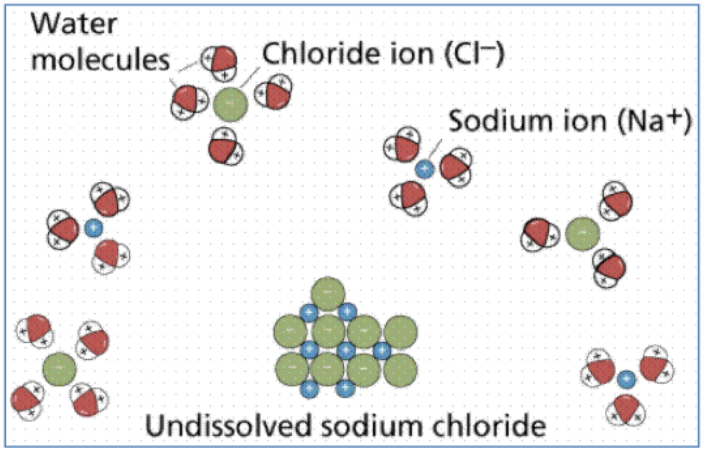
Learning Goals: I will be able to…

1. **Identify** and **determine** whether an aqueous solution is neutral, acidic or basic from its salt.
2. **Know** the solution produce by dissolve metal oxide or non-metal oxide in water

Salts in Solution

- A **salt** is an ionic solid that contains cations and anions in a repeating crystalline pattern
- Salts are electrolytes (they dissociate into ions) when they dissolve in water

$$NaCl(s) \rightleftarrows Na^+(aq) + Cl^-(aq)$$



- Neutral salts produce neither hydrogen ions or hydroxide ions when they dissolve in water
- Basic salts will increase the hydroxide ion concentration when they dissolve in water
- Acidic salts will increase the hydrogen ion concentration when dissolved in water

Salts That Produce Neutral Solutions

Example – solution of $MgBr_2$, salt of strong acid and strong base

Formation: $2HBr_{(aq)} + Mg(OH)_{2(aq)} \rightarrow 2H_2O_{(l)} + MgBr_{2(aq)}$

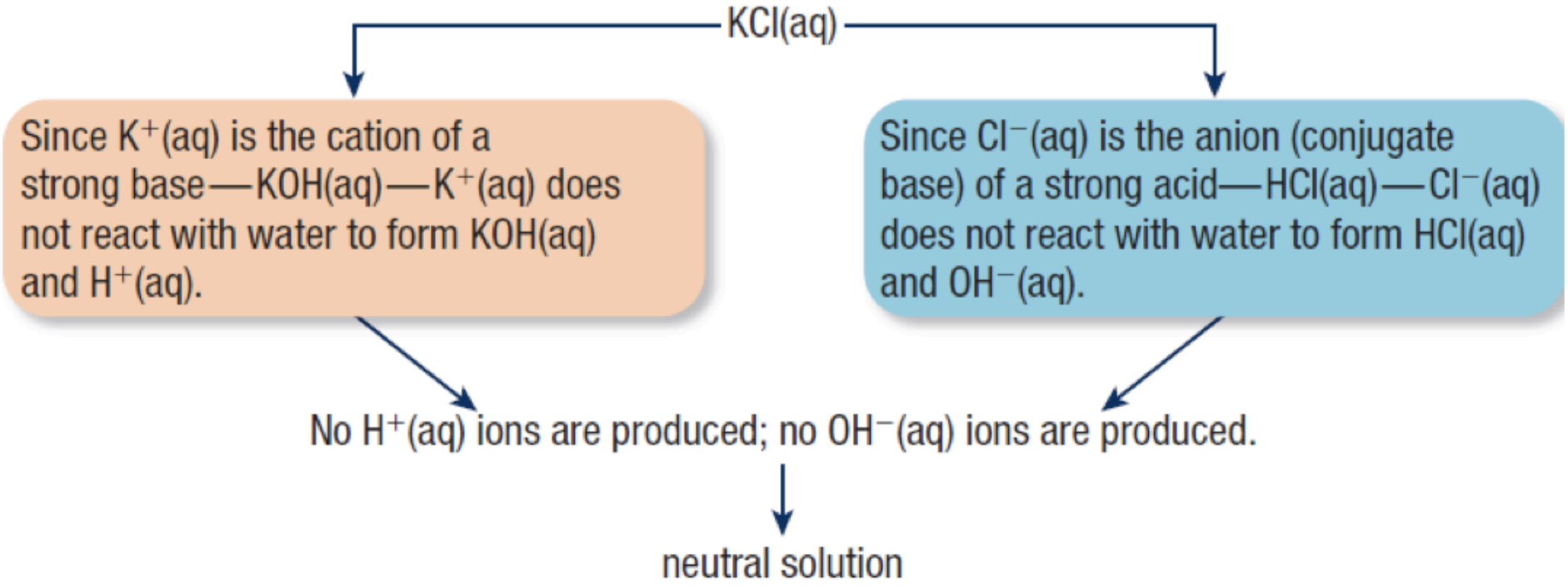
Dissolution: $MgBr_{2(aq)} \rightarrow Mg^{2+}_{(aq)} + 2Br^-_{(aq)}$

Weak conjugate acid of strong base → $Mg^{2+}_{(aq)} + H_2O_{(l)}$ ~~→~~ No reaction

Weak conjugate base of strong acid → $Br^-_{(aq)} + H_2O_{(l)}$ ~~→~~ No reaction

Weak conjugate acid and base do not hydrolyze (do not react with water) → pH = 7

Salts That Produce Neutral Solutions



Salts That Produce Basic Solutions

Example – aqueous solution of NH_4NO_3, which is salt of strong acid (HNO_3) and weak base (NH_3):

Formation: $HNO_{3(aq)} + NH_{3(aq)} \rightarrow NH_4NO_{3(aq)}$

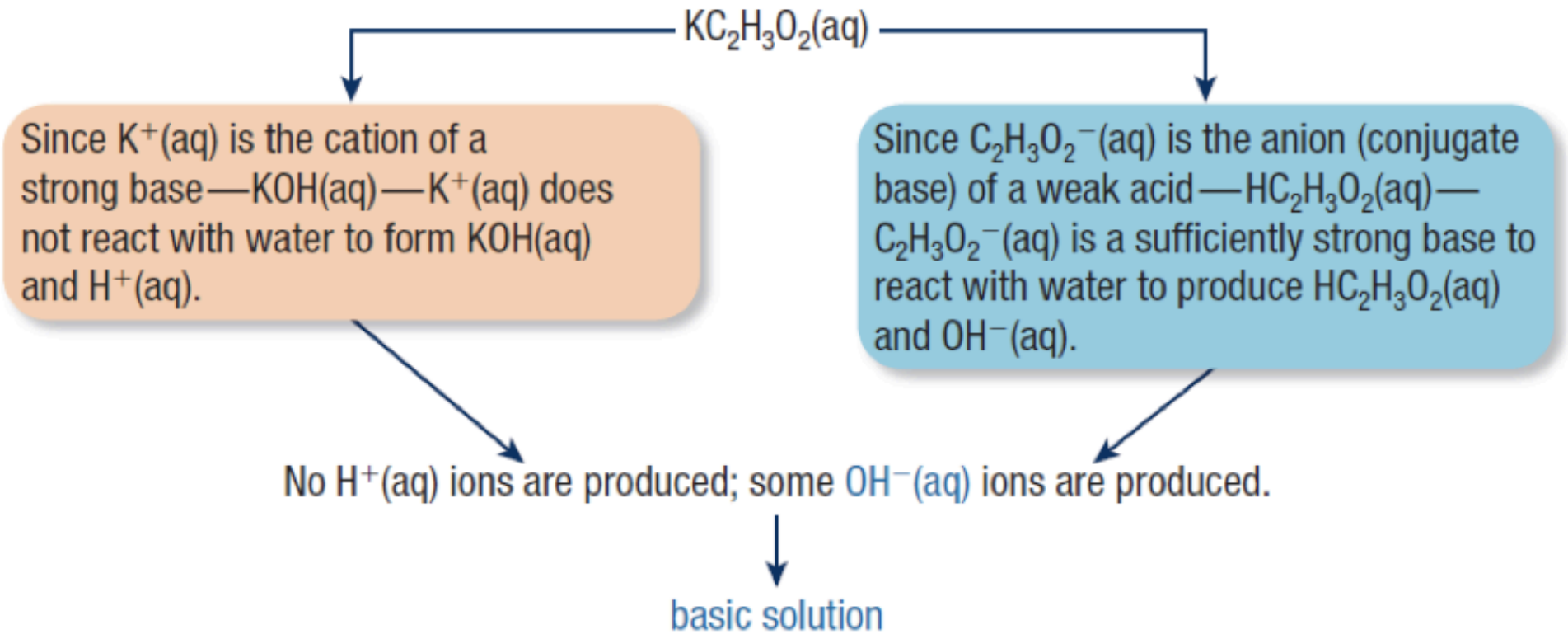
Dissolution: $NH_4NO_{3(aq)} \rightarrow NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$

Weak conjugate base of strong acid → $NO_3^-{}_{(aq)} + H_2O_{(l)} \not\rightarrow$ No reaction

Strong conjugate acid of weak base → $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+{}_{(aq)} + NH_{3(aq)}$ Reaction!

Conjugate acid of the weak base is strong thus it will hydrolyze → pH < 7

Salts That Produce Basic Solutions



Salts That Produce Acidic Solutions

Example – solution of NaF, salt of weak acid and strong base

Formation: $NaOH_{(aq)} + HF_{(aq)} \rightarrow H_2O_{(l)} + NaF_{(aq)}$

Dissolution: $NaF_{(aq)} \rightarrow Na^+_{(aq)} + F^-_{(aq)}$

Weak conjugate acid of strong base

$Na^+_{(aq)} + H_2O_{(l)} \not\rightarrow$ No reaction

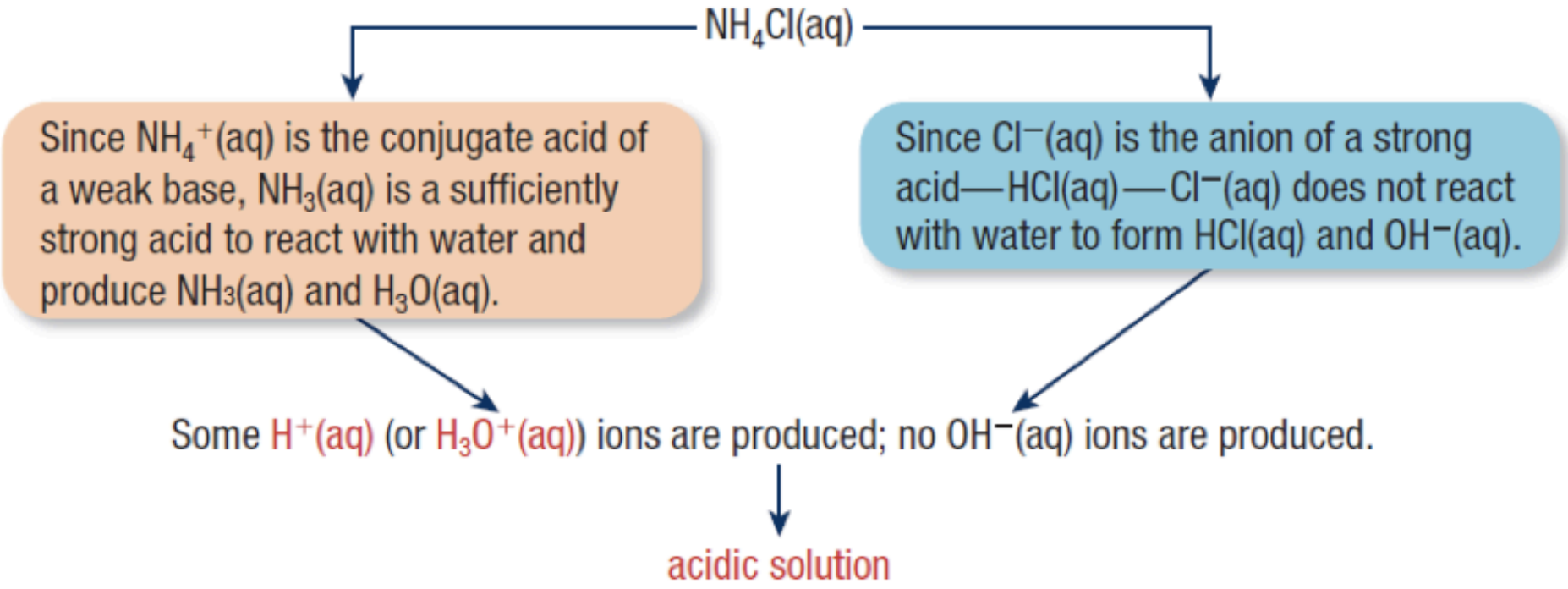
Strong conjugate base of weak acid

$F^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HF_{(aq)} + OH^-_{(aq)}$

Reaction!

Conjugate base of a weak acid is strong, it will hydrolyze → pH > 7

Salts That Produce Acidic Solutions



Salt of Weak Acid/Weak Base

- Conjugate base of the weak acid will hydrolyze, as will the conjugate acid of the weak base. One must look at the pK_a and pK_b to predict the pH of solution.

Example – solution of $C_2H_5NH_3C_7H_5O_2$, (ethylammonium benzoate), salt of weak acid and weak base

Formation: $C_7H_5O_2H_{(aq)} + C_2H_5NH_{2(aq)} \rightarrow C_2H_5NH_3C_7H_5O_{2(aq)}$

Dissolution: $C_2H_5NH_3C_7H_5O_{2(aq)} \rightarrow C_2H_5NH_3^+{}_{(aq)} + C_7H_5O_2^-{}_{(aq)}$

Strong conjugate acid of weak base → $C_2H_5NH_3^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + C_2H_5NH_{2(aq)}$ *Reaction!*

Strong conjugate base of weak acid → $C_7H_5O_2^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons C_7H_5O_2H_{(aq)} + OH^-{}_{(aq)}$ *Reaction!*

How do we predict which wins out in this competition?

Salt of Weak Acid/Weak Base

- If $K_a > K_b$, the solution will be acidic.
- If $K_a < K_b$, the solution will be basic.
- If $K_a = K_b$, the solution will be neutral.

Practice

Calculate the pH of a 0.20 mol/L solution of ammonium chloride $NH_4Cl_{(aq)}$

Table 3 Acid–Base Properties of Various Types of Salts

Type of salt	Examples	Comment	pH of solution
Cation of a Group 1 or Group 2 element, other than Be; anion is from strong acid	KCl(aq), NaCl(aq), $NaNO_3(aq)$	Neither of the ions acts as an acid or a base	neutral
Cation of a Group 1 or Group 2 element, other than Be; anion is from weak acid	$NaC_2H_3O_2(aq)$, KCN(aq), NaF(aq)	Anion acts as a base; cation has no effect on pH	basic
Cation is conjugate acid of weak base; anion is from strong acid	$NH_4Cl(aq)$, $NH_4NO_3(aq)$	Cation acts as an acid; anion has no effect on pH	acidic
Cation is conjugate acid of weak base; anion is conjugate base of weak acid	$NH_4C_2H_3O_2(aq)$, $NH_4CN(aq)$	Cation acts as an acid; anion acts as a base	acidic if $K_a > K_b$ basic if $K_b > K_a$ neutral if $K_a = K_b$
Cation is highly charged metal ion; anion is from strong acid	$Al(NO_3)_3(aq)$, $FeCl_3(aq)$	Hydrated cation acts as an acid; anion has no effect on pH	acidic

Hydrolysis of Amphiprotic Ions

$NaHSO_4(aq) \rightarrow Na^+(aq) + HSO_4^-(aq)$

(dissociation)

$HSO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_4^{2-}(aq) \quad K_a = 1.2 \times 10^{-2}$

(acid hydrolysis)

$HSO_4^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + H_2SO_4(aq) \quad K_b = \text{very small}$

(base hydrolysis)

Hydrolysis of Metallic and Non-metallic Oxides

- **Metallic oxides** dissolve in water to produce *basic* solutions

$$CaO(s) + H_2O(l) \rightleftharpoons Ca^{2+}(aq) + 2\,OH^-(aq)$$

- **Non-metallic oxides** dissolve in water to produce *acidic* solutions

$$CO_2(g) + H_2O(l) \rightleftharpoons \cancel{H_2CO_3(aq)}$$
$$\cancel{H_2CO_3(aq)} + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$
$$CO_2(g) + 2\,H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq) \quad \text{(net equation)}$$

Did You Learn?

- For a salt solution in which the anion is the conjugate base of a weak acid, and the cation does not react with water, the aqueous solution is basic.
- For a salt solution in which the cation is the conjugate acid of a weak base, and the anion does not react with water, the aqueous solution is acidic.
- If neither the anion nor the cation is a conjugate base or acid, the ions will not affect the pH of the aqueous solution.
- If the salt has an anion and a cation that can both hydrolyze water, look at the K_b and K_a values of the anion and cation.
  - If $K_a > K_b$, the solution will become more acidic
  - If $K_a < K_b$, the solution will become more basic
  - If $K_a = K_b$, the solution will be neutral
- Metallic oxides form basic solutions and non-metallic oxides form acidic solutions.

HOMEWORK

Required Reading:

p. 531 – 539

(remember to supplement your notes!)

Questions:

P. 534 #1, 2

P. 536 #1, 2

P. 538 #1, 2

P. 539 #2, 4, 5