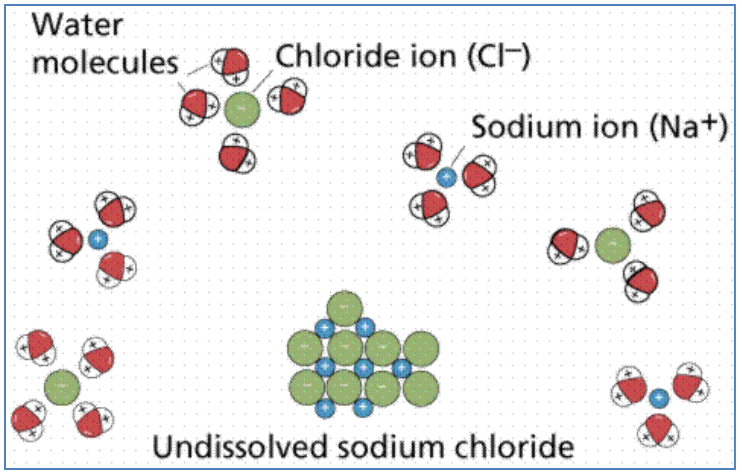
Acid-Base Properties of Salt Solutions

Chapter 8.6

Salts in Solution

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



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

- 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

Salts of strong acids/strong bases

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

$2HBr_{(aq)} + Mg(OH)_{2\,(aq)} \rightarrow 2\,H_2O_{(l)} + MgBr_{2\,(aq)}$ *formation*

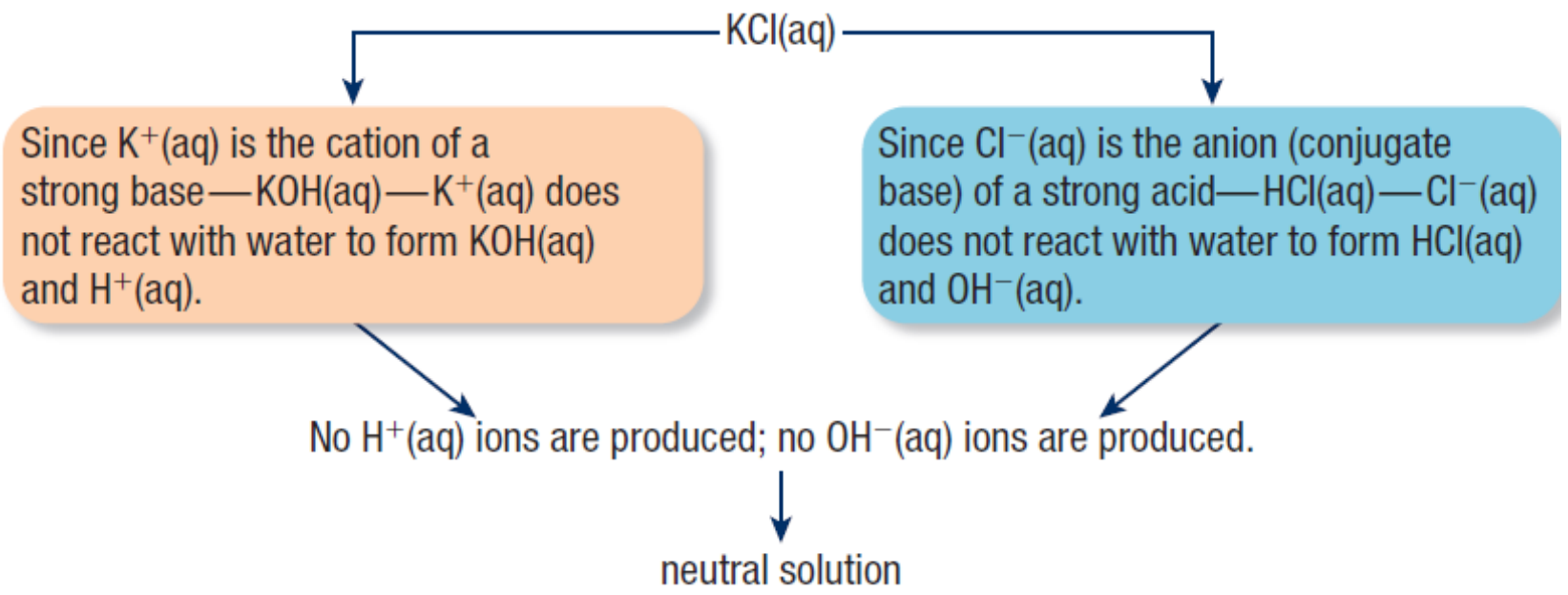
$MgBr_{2\,(aq)} \rightarrow Mg^{2+}_{(aq)} + 2\,Br^-_{(aq)}$ *dissolution*

Weak conjugate acid of strong base → $Mg^{+2}_{(aq)} + \cancel{H_2O} \rightarrow$ No *reaction*

Weak conjugate base of strong acid → $Br^-_{(aq)} + \cancel{H_2O} \rightarrow$ No *reaction*

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

Salts That Produce Neutral Solutions



Salts That Produce Basic Solutions

Salt of Strong Acid/Weak Base

Salts of strong acids/weak bases

Example **– aqueous solution of NH_4NO_3,**

which is salt of strong acid (HNO_3) and weak base (NH_3):

$$HNO_{3(aq)} + NH_{3\,(aq)} \rightarrow NH_4NO_{3\,(aq)}$$ ***formation***

$$NH_4NO_{3\,(aq)} \rightarrow NH_4^{+}{}_{(aq)} + NO_3^{-}{}_{(aq)}$$ ***dissolution***

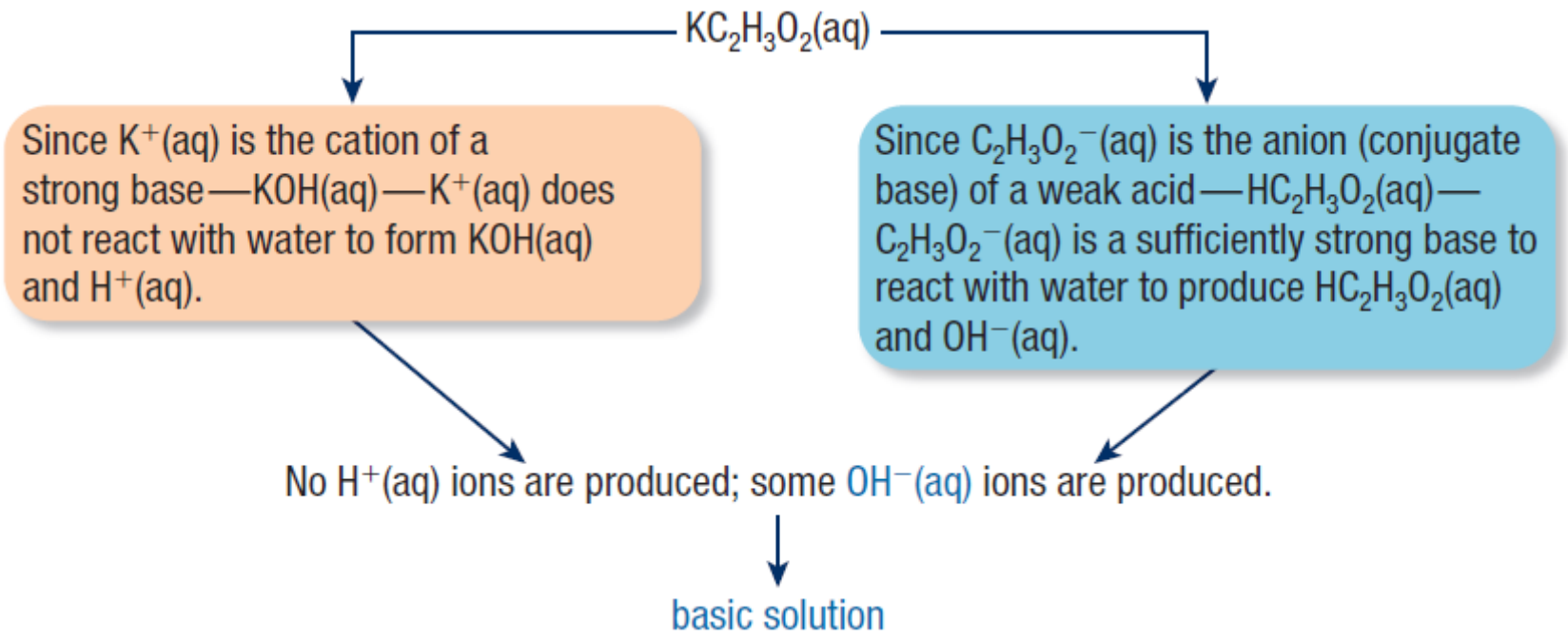
Weak conjugate base of strong acid → $NO_3^{-}{}_{(aq)} + H_2O \rightarrow$ **No *reaction***

Strong conjugate acid of weak base → $NH_4^{+}{}_{(aq)} + H_2O \rightarrow H_3O^{+}{}_{(aq)} + NH_{3\,(aq)}$ ***reaction!***

Conjugate acid of the weak base is strong thus it will hydrolyze

$\Rightarrow$ pH < 7

Salts That Produce Basic Solutions



Salts That Produce Acidic Solutions

Salt of Weak Acid/Strong Base

Salts of weak acids/strong bases

Example **– solution of NaF, salt of weak acid + strong base**

$$NaOH_{(aq)} + HF_{(aq)} \rightarrow H_2O_{(l)} + NaF_{(aq)} \quad \textit{formation}$$

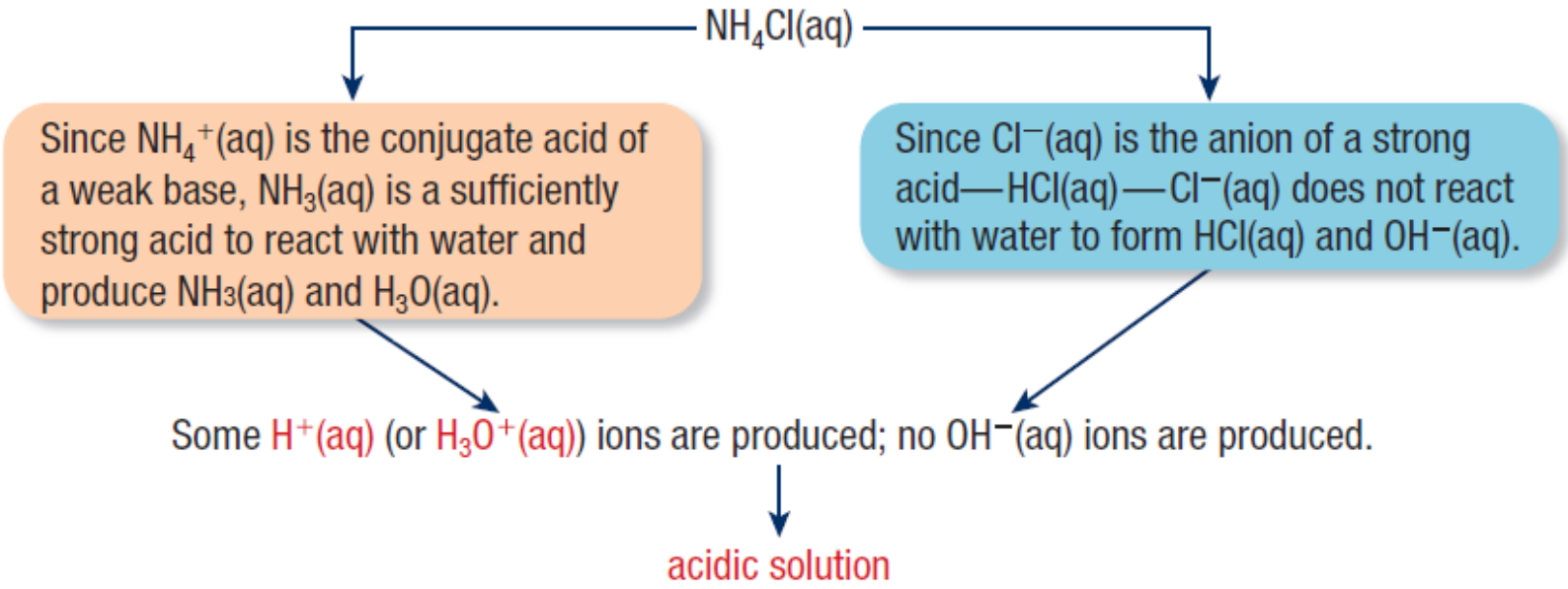
$$NaF \rightarrow Na^+_{(aq)} + F^-_{(aq)} \quad \textit{dissolution}$$

Weak conjugate acid of strong base → $Na^+_{(aq)} + H_2O \not\rightarrow$ No *reaction*

Strong conjugate base of weak acid → $F^-_{(aq)} + H_2O \rightleftarrows HF_{(aq)} + OH^-_{(aq)}$ *reaction!*

Conjugate base of the weak acid is strong, it will hydrolyze ⇒ pH > 7

Salts That Produce Acidic Solutions



Salt of Weak Acid/Weak Base

Salts of weak acids/weak bases

-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 + weak base**

$$C_7H_5O_2H_{(aq)} + C_2H_5NH_{2\,(aq)} \rightarrow C_2H_5NH_3C_7H_5O_{2\,(aq)}$$ *formation*

$$C_2H_5NH_3C_7H_5O_{2\,(aq)} \rightarrow C_2H_5NH_3^+{}_{(aq)} + C_7H_5O_2^-{}_{(aq)}$$ *dissolution*

$$C_2H_5NH_3^+{}_{(aq)} + H_2O \rightarrow H_3O^+{}_{(aq)} + C_2H_5NH_{2\,(aq)}$$ *reaction!*

Strong conjugate acid of weak base

$$C_7H_5O_2^-{}_{(aq)} + H_2O \rightleftharpoons C_7H_5O_2H_{(aq)} + OH^-{}_{(aq)}$$ *reaction!*

Strong conjugate base of weak acid

How do we predict which wins out in this competition?

But there's a fourth option!

- If the K_a value for the acidic ion is larger than the K_b value for the basic ion, the solution will be acidic.
- If the K_b value is larger than the K_a value, the solution will be basic.
- Equal K_a and K_b values result in a neutral solution.

Summary

Behavior of Salts in Water

Table 18.8 The Behavior of Salts in Water

Salt Solution (Examples)	pH	Nature of Ions	Ion That Reacts with Water	
Neutral [NaCl, KBr, $Ba(NO_3)_2$]	7.0	Cation of strong base Anion of strong acid	None	
Acidic [NH_4Cl, NH_4NO_3, CH_3NH_3Br]	<7.0	Cation of weak base Anion of strong acid	Cation	
Acidic [$Al(NO_3)_3$, $CrCl_3$, $FeBr_3$]	<7.0	Small, highly charged cation Anion of strong acid	Cation	
Basic [CH_3COONa, KF, Na_2CO_3]	>7.0	Cation of strong base Anion of weak acid	Anion	

Practice

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

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

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

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 #1-7