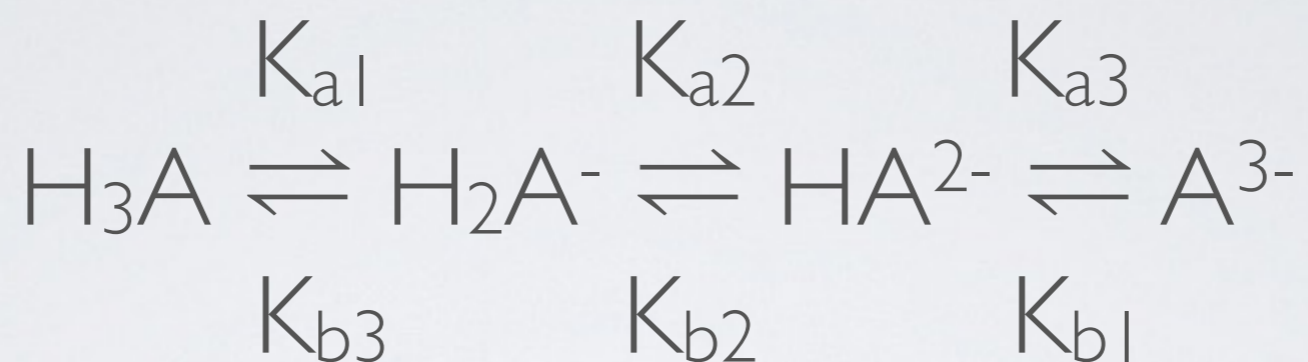


# 21 - POLYPROTIC ACIDS & BASES

CHEM 251 SDSU

# POLYPROTIC $K_A$ & $K_B$ VALUES



The  $K_a$  and  $K_b$  values are numbered in order of the strength of the equilibrium to act as an acid or base. The lower the number the further the reaction shifts to the products.

$K_{a1}$  good acid;  $K_{b3}$  bad base

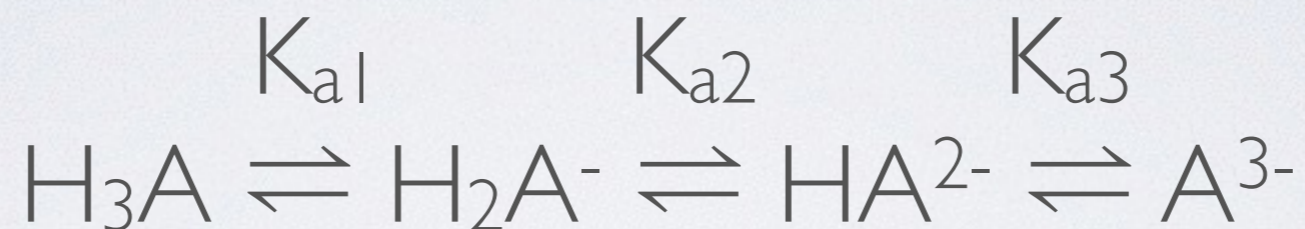
$K_{a3}$  bad acid;  $K_{b1}$  good base

# PH OF ACIDS/BASES

- The pH of a weak acid or a weak base solution is dependent on the  $pK_a$  of that particular acid/base and its concentration in the solution.
- When an acid/base has more than one  $pK_a$  (polyprotic), the pH is dependent on the prominent form(s) of the acid/base in the solution.
- At its simplest, the polyprotic acid can be treated as a monoprotic acid/base if a solution is prepared directly from the full protonated, or fully deprotonated form.

# PH OF A POLYPROTIC SOLUTION

The pH of a solution will depend on the primary form of the acid (base) present

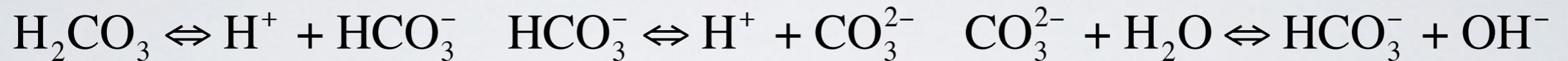


<u>Species:</u>	<u>Relevant Reactions:</u>	<u>Equilibria:</u>
$H_3A$	$H_3A \rightleftharpoons H_2A^- + H^+$	$K_{a1}$
$NaH_2A$	$H_3A + OH^- \rightleftharpoons H_2A^- \rightleftharpoons HA^{2-} + H^+$	$K_{a1} \text{ \& } K_{a2}$
$K_2HA$	$H_2A^- + OH^- \rightleftharpoons HA^{2-} \rightleftharpoons A^{3-} + H^+$	$K_{a2} \text{ \& } K_{a3}$
$Li_3A$	$HA^{2-} + OH^- \rightleftharpoons A^{3-} + H_2O$	$K_{a3}$

# PROBLEMS

What is the pH of a 36 mM solution of:

- **Carbonic acid (H<sub>2</sub>CO<sub>3</sub>)?**
- Sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>)?
- Sodium bicarbonate (NaHCO<sub>3</sub>)?



36mM H<sub>2</sub>CO<sub>3</sub> treat like a weak monoprotic acid (HA)

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} = 4.46 \times 10^{-7} \quad [\text{HA}] = 0.036 - x \quad [\text{H}^+] = [\text{A}^-] = x$$

$$4.46 \times 10^{-7} = \frac{(x)(x)}{0.036 - x} \quad 1.6056 \times 10^{-8} - 4.46 \times 10^{-7}(x) = x^2$$

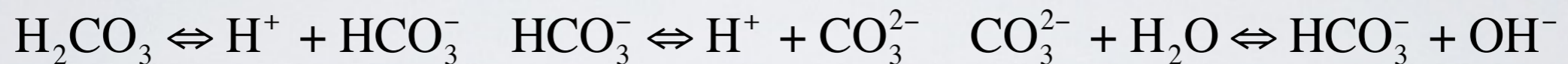
$$0 = x^2 + 4.46 \times 10^{-7}(x) - 1.6056 \times 10^{-8}$$

$$x = [\text{H}^+] = 1.26 \times 10^{-4} \text{ M} \quad \text{pH} = -\log(1.26 \times 10^{-4}) = 3.90$$

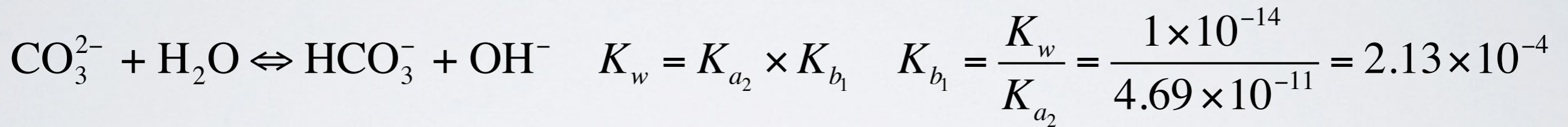
# PROBLEMS

What is the pH of a 36 mM solution of:

- Carbonic acid ( $\text{H}_2\text{CO}_3$ )?
- **Sodium carbonate ( $\text{Na}_2\text{CO}_3$ )?**
- Sodium bicarbonate ( $\text{NaHCO}_3$ )?



36mM  $\text{Na}_2\text{CO}_3$  treat like a weak monoprotic base ( $\text{A}^{2-}$ )



$$K_{b_1} = \frac{[\text{HA}^-][\text{OH}^-]}{[\text{A}^{2-}]} = 2.13 \times 10^{-4} \quad [\text{A}^{2-}] = 0.036 - x \quad [\text{HA}^-] = [\text{OH}^-] = x$$

$$2.13 \times 10^{-4} = \frac{(x)(x)}{0.036 - x} \quad 7.668 \times 10^{-6} - 2.13 \times 10^{-4}(x) = x^2$$

$$0 = x^2 + 2.13 \times 10^{-4}(x) - 7.668 \times 10^{-6}$$

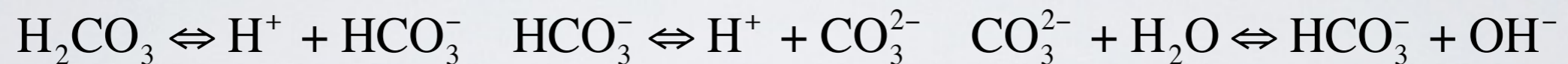
$$x = [\text{OH}^-] = 2.66 \times 10^{-3} \text{ M} \quad \text{pOH} = -\log(2.66 \times 10^{-3}) = 2.57$$

$$\text{pH} = 14 - \text{pOH} \quad \text{pH} = 14 - 2.57 = 11.43$$

# PROBLEMS

What is the pH of a 36 mM solution of:

- Carbonic acid ( $\text{H}_2\text{CO}_3$ )?
- Sodium carbonate ( $\text{Na}_2\text{CO}_3$ )?
- **Sodium bicarbonate ( $\text{NaHCO}_3$ )?**



$$[\text{H}^+] = \sqrt{\frac{K_{a1}K_{a2}F + K_{a1}K_w}{K_{a1} + F}}$$

$$F = 0.036\text{M} \quad K_{a1} = 4.46 \times 10^{-7} \quad K_{a2} = 4.69 \times 10^{-11}$$

$$[\text{H}^+] = \sqrt{\frac{(4.46 \times 10^{-7})(4.69 \times 10^{-11})(0.036) + (4.46 \times 10^{-7})(1 \times 10^{-14})}{(4.46 \times 10^{-7}) + (0.036)}}$$

$$[\text{H}^+] = 4.59 \times 10^{-9}\text{M} \quad \text{pH} = -\log(4.59 \times 10^{-9}) = 8.34$$