or Chapter 9

① $HA^- \rightleftharpoons A^{2-} + H^+ \quad K = 10^{-4}$

$HA^- + H_2O \rightleftharpoons H_2A + OH^- \quad K = 10^{-8}$

The H^+ in the first reaction reacts with OH^- from the second reaction drawing the second reaction further towards products than expected.

② $^+H_3N-CH(R)-CO_2^-$ all amino acids are diprotic (2 pKas) and some have an additional acid group on their side chain.

④a $H_2A \rightleftharpoons H^+ + HA^- \quad K_a = 1.00\times10^{-4}$

$$\frac{[H^+][HA^-]}{[H_2A]} = 1.00\times10^{-4}$$

	H_2A	H^+	HA^-
I	0.100	-	-
C	-x	+x	+x
E	0.100-x	x	x

$$\frac{x^2}{0.100-x} = 1.00\times10^{-4}$$

$$x^2 + 1.00\times10^{-4} - 1.00\times10^{-5} = 0$$

$$x = 3.11\times10^{-3} = [H^+]$$

$$\frac{[H^+][A^{2-}]}{[HA]} = 1.00\times10^{-8}$$

$$[A^{2-}] = 1.00\times10^{-8}$$

pH = 2.51

$[H_2A] = 9.69\times10^{-2}$ M

$[HA^-] = 3.11\times10^{-3}$ M

$[A^{2-}] = 1.00\times10^{-8}$ M

4b. $[H^+] = \sqrt{\dfrac{(1.00\times10^{-4})(1.00\times10^{-8})(0.100) + (1.00\times10^{-4})(1.00\times10^{-14})}{1.00\times10^{-4} + 0.100}}$

$= 1.00\times10^{-6} \Rightarrow pH = 6$

$[H_2A] = \dfrac{[H^+][HA^-]}{1.00\times10^{-4}} = \dfrac{(1.00\times10^{-6})(0.100)}{1.00\times10^{-4}} = \boxed{1.00\times10^{-3} M}$

$[HA^-] = F = \boxed{0.100 M}$

$[A^{2-}] = \dfrac{[HA^-](1.00\times10^{-8})}{[H^+]} = \dfrac{(0.100)(1.00\times10^{-8})}{1.00\times10^{-6}} = \boxed{1.00\times10^{-3} M}$

c. $A^{2-} + H_2O \rightleftharpoons HA^- + OH^-$ $K_{B1} = \dfrac{10^{-14}}{K_{A2}} = 1.00\times10^{-6}$

$\dfrac{[HA^-][OH^-]}{[A^{2-}]} = 1.00\times10^{-6}$

	A^-	OH^-	HA^-
I	0.100	-	-
C	-x	+x	+x
E	0.100-x	x	x

$\dfrac{x^2}{0.100-x} = 1.00\times10^{-6}$

$x = 3.16\times10^{-4} M$

$pH = -\log \dfrac{10^{-14}}{3.16\times10^{-4}} = \boxed{10.5}$

$[HA^-] = \boxed{3.16\times10^{-4} M}$

$[A^{2-}] = \boxed{0.0997 M}$

$[H_2A] = K_{B2} = \boxed{1.00\times10^{-10} M}$

5a. $K_{a1} = 1.42\times10^{-3}$

$K_{a2} = 2.01\times10^{-6}$

$\dfrac{x^2}{0.100-x} = 1.42\times10^{-3}$

$x^2 + 1.42\times10^{-3}x - 1.42\times10^{-4}$

$x = 1.12\times10^{-2} = [H^+]$

$pH = 1.95$

$[H_2A] = 0.089 M$

$[HA^-] = 1.12\times10^{-2} M$

$[A^{2-}] = 2.01\times10^{-6} M$

5b. $[H^+] = \sqrt{\frac{(1.42\times10^{-3})(2.01\times10^{-6})(0.100) + (1.42\times10^{-3})(10^{-14})}{1.42\times10^{-3} + 0.100}}$

$[H^+]: 5.30\times10^{-5}$

$[H_2A] = \frac{[H^+][HA^-]}{K_{a1}} = \frac{(5.30\times10^{-5})(0.100)}{1.42\times10^{-3}}$

$= 3.7\times10^{-3}$

$[A^{2-}] = \frac{K_{a2}[HA^-]}{[H^+]} = \frac{(2.01\times10^{-6})(0.100)}{5.30\times10^{-5}}$

$= 3.79\times10^{-3}$

pH = 4.28
$[HA^-] = 0.100M$
$[H_2A] = 3.7\times10^{-3}M$
$[A^{2-}] = 3.8\times10^{-3}M$

c. $\frac{x^2}{0.100-x} = K_{B1} = \frac{10^{-14}}{K_{a2}} = 4.98\times10^{-9}$

$x = 2.23\times10^{-5} = [OH^-]$

$pH = -\log\frac{10^{-14}}{[OH^-]} = 9.35$

pH = 9.35
$A^{2-} = 0.100M$
$HA^- = 2.23\times10^{-5}M$
$H_2A = K_{B2} = 2.04\times10^{-12}M$

6. $K_{a1} = 4.65\times10^{-6}$ $K_{B1} = 10^{-14}/1.86\times10^{-10} = 5.38\times10^{-5}$

$K_{a2} = 1.86\times10^{-10}$ $K_{B2} = 10^{-14}/4.65\times10^{-6} = 2.15\times10^{-9}$

$\frac{x^2}{0.300-x} = 5.38\times10^{-5}$

$x = 4.02\times10^{-3} = [OH^-]$

$pH = -\log\left(\frac{10^{-14}}{[OH^-]}\right) =$

$[BH_2^{2+}] = \frac{K_{B2}[BH^+]}{[OH^-]} = 2.15\times10^{-9}$

pH = 11.6
$[B] = 0.296M$
$[BH^+] = 4.02\times10^{-3}M$
$[BH_2^+] = 2.15\times10^{-9}M$