Chemistry 255
Spring 2011
Problem Set #3
Answer Key

1.a) $K_a = 3.24\times10^{-4}$ Aspirin = HA $HA \Leftrightarrow H^+ + A^-$

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{x^2}{(0.492-x)} = 3.24\times10^{-4} \text{ since } [H^+] = [A^-]$$

$$x^2 = (0.492-x)3.24\times10^{-4}$$

$$x^2 + 3.24\times10^{-4}x - 1.5941\times10^{-4} = 0$$

solve using quadratic equation : $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

$$x = \frac{-3.24\times10^{-4} \pm \sqrt{(3.24\times10^{-4})^2 - 4(-1.5941\times10^{-4})}}{2}$$

$$x = 1.246\times10^{-2} = [H^+]$$

$$pH = -\log(1.246\times10^{-2}) = 1.904$$

b) $\alpha = \frac{x}{F} = \frac{1.246\times10^{-2}}{0.492} = 0.0253$ or 2.53% is in $[A^-]$ form, the rest (100 - 2.53) = 97.47% is in [HA] form.

2. $XH^+Cl^-(s) \Leftrightarrow XH^+ + Cl^-$ $K_{sp} = 2.9\times10^{-2}$ pH = 7.40 $[H^+] = 3.981\times10^{-8}$ M

$XH^+ \Leftrightarrow H^+ + X$ $K_a = 8.3\times10^{-5}$

Mass Balance : $[XH^+] + [X] = [Cl^-]$

Charge Balance : $[Cl^-] + [OH^-] = [H^+] + [XH^+]$

$$8.3\times10^{-5} = \frac{[H^+][X]}{[XH^+]} = \frac{(3.981\times10^{-8})[X]}{[XH^+]} \Rightarrow 8.3\times10^{-5}[XH^+] = 3.981\times10^{-8}[X]$$

$$K_{sp} = [XH^+][Cl^-] = 2.9\times10^{-2}$$

from K_{sp} : $[Cl^-] = \frac{2.9\times10^{-2}}{[XH^+]}$

put into mass balance : $[XH^+] + [X] = \frac{2.9\times10^{-2}}{[XH^+]} \Rightarrow [XH^+]^2 + [XH^+][X] = 2.9\times10^{-2}$

from K_a : $8.3\times10^{-5}[XH^+] = 3.981\times10^{-8}[X] \Rightarrow 2084.90[XH^+] = [X]$

plug into $[XH^+]^2 + [XH^+][X] = 2.9\times10^{-2}$

$[XH^+]^2 + [XH^+](2084.90[XH^+]) = 2.9\times10^{-2}$

$2085.90[XH^+]^2 = 2.9\times10^{-2}$

$[XH^+] = 3.729\times10^{-3}\,M$

solve for Cl^- : $[Cl^-] = 7.7776 = 7.8M$

3. $HM \Leftrightarrow H^+ + M^-$

$pH = 2.985 \quad [H^+] = 1.035\times10^{-3} = [M^-]$

$[HM]_{final} = 4.50\times10^{-2} - 1.035\times10^{-3} = 4.396\times10^{-2}$

$$K_a = \frac{[H^+][M^-]}{[HM]} = \frac{\left(1.035\times10^{-3}\right)^2}{4.396\times10^{-2}} = 2.4365\times10^{-5}$$

$pK_a = -\log(K_a) = 4.613$

4. $B + H_2O \Leftrightarrow BH^+ + OH^-$

$$K_b = \frac{[BH^+][OH^-]}{[B]} \Rightarrow 4.50\times10^{-5} = \frac{x^2}{0.48 - x}$$

$2.16\times10^{-5} - 4.50\times10^{-5}\,x = x^2$

$x^2 + 4.50\times10^{-5}\,x - 2.16\times10^{-5} = 0$

plug into quadratic formula : $x = \dfrac{-4.50\times10^{-5} \pm \sqrt{(4.50\times10^{-5})^2 - 4(-2.16\times10^{-5})}}{2} = 4.625\times10^{-3} = [OH^-]$

$[OH^-] = 4.6\times10^{-3}\,M$

$pOH = 2.33$

$pH = 11.665 \approx 11.67$

5. a) Ephedrine $K_b = 2.30\times10^{-5}$ $\qquad K_a = \dfrac{K_w}{K_b} = \dfrac{1.00\times10^{-14}}{2.30\times10^{-5}} = 4.35\times10^{-10}$

b) Lidocaine $K_a = 1.38\times10^{-8}$

Lidocaine has the larger K_a and is therefore the stronger acid.

$$B + H_2O \Leftrightarrow BH^+ + OH^-$$

$$K_b = \frac{[BH^+][OH^-]}{[B]} \Rightarrow 6.3\times10^{-5} = \frac{x^2}{0.060 - x}$$

6. plug into quadratic formula : $x = 1.9_1 \times 10^{-3} = [OH^-]$

$[OH^-] = 1.9_1 \times 10^{-3} M$

$pH = 11.28$

$[BH^+] = x = 1.9_1 \times 10^{-3} M$

$[B] = F - x = 0.058M$