CHEM 1105 **ANSWERS TO PROBLEM SET 7**

1. $[NaH_2PO_4] = [H_2PO_4^-] = 0.125\ M$

molarity	$H_2PO_4^-$	$\rightleftharpoons$	H^+	+	HPO_4^{2-}
initial:	0.125		0		0
change:	-x		x		x
equilibrium:	0.125 - x		x		x

$$K_a = \frac{[H^+][HPO_4^{2-}]}{[H_2PO_4^-]} = 6.2 \times 10^{-8} = \frac{x^2}{0.125-x}$$

Since K_a is small, x is small, and $0.125-x \approx 0.125$

$$\frac{x^2}{0.125} = 6.2 \times 10^{-8} \qquad x^2 = 7.75 \times 10^{-9}$$

$x = 8.8 \times 10^{-5} = [H^+]$

pH = 4.1

$$\text{Error in approximation} = \frac{8.8 \times 10^{-5}}{0.125} \times 100 = 0.070\%$$

2. For a buffer, $[H^+] = K_a \times \frac{[\text{Acid}]}{[\text{Conjugate base}]}$

The acid is H_3PO_4 and the conjugate base is $H_2PO_4^-$

$$K_a = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{1.3 \times 10^{-12}} = 7.7 \times 10^{-3}$$

$$[H^+] = 7.7 \times 10^{-3} \times \frac{0.30}{0.20} = 1.2 \times 10^{-2} \qquad \text{pH} = 1.9$$

3.

molarity	$CH_3NH_2 + H_2O$	$\rightleftharpoons$	$CH_3NH_3^+$	+	HO^-
initial:	0.222		0		0
change:	-x		x		x
equilibrium:	0.222-x		x		x

$$K_b = \frac{[CH_3NH_3^+][HO^-]}{[CH_3NH_2]} = \frac{x^2}{0.222-x} = 5.0 \times 10^{-4}$$

Since K_b is small, x is small, and $0.222-x \approx 0.222$

$$\frac{x^2}{0.222} = 5.0 \times 10^{-4} \qquad x^2 = 1.11 \times 10^{-4}$$

$x = 1.05 \times 10^{-2} = [HO^-]$

pOH = 2.0 pH = 14 - pOH = 12.0

4. $OH^- + C_6H_5NH_3^+ \rightleftharpoons C_6H_5NH_2 + H_2O \quad K = 2.2 \times 10^9$

For $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$, $K = K_b$ for $C_6H_5NH_2$

$$K = \frac{1}{2.2 \times 10^9} = 4.55 \times 10^{-10} = K_b$$

The conjugate acid of $C_6H_5NH_2$ is $C_6H_5NH_3^+$

Therefore, K_a for $C_6H_5NH_3^+ = \frac{1.0 \times 10^{-14}}{4.55 \times 10^{-10}} = 2.2 \times 10^{-5}$

5.

molarity	HA	$\rightleftharpoons$	H^+	+	A^-
initial:	0.050		0		0

change: $- \frac{3.5}{100} \times 0.050 = -0.000175$ +0.000175 +0.000175

equilibrium: 0.050-0.000175 = 0.0498 0.000175 0.000175

(i) $[H^+] = 1.75 \times 10^{-4}$ pH = 3.8

(ii) $K_a = \frac{(1.75 \times 10^{-4})^2}{0.0498} = 6.1 \times 10^{-7}$

6. $pK_b = 5.4$ $K_b = 4.0 \times 10^{-6}$

molarity	B	+ H_2O	⇌	BH^+	+ OH^-
initial:	0.10			0	0
change:	-x			x	x
equilibrium:	0.10-x			x	x

$K_b = \frac{[BH^+][OH^-]}{[B]} = \frac{x^2}{0.10-x} = 4.0 \times 10^{-6}$

Since K_b is small, x is small, and 0.10-x ≈ 0.10

$x^2 = \frac{4.0 \times 10^{-6}}{0.10}$ $x^2 = 4.0 \times 10^{-7}$ $x = 6.3 \times 10^{-4}$

Percent dissociation = $\frac{6.3 \times 10^{-4}}{0.10} \times 100 = 0.63\%$

7. The solution of HOC_6H_5 and $NaOC_6H_5$ is a buffer solution.

$[H^+] = K_a \times \frac{[HOC_6H_5]}{[NaOC_6H_5]} = K_a \times \frac{\text{moles } HOC_6H_5}{\text{moles } NaOC_6H_5}$

$= 1.6 \times 10^{-10} \times \frac{2.5/94}{3.5/116} = 1.4 \times 10^{-10}$

pH = 9.85

8. The solution of CH_3COONa and CH_3COOH is a buffer solution.

$[H^+] = K_a \times \frac{[CH_3COOH]}{[CH_3COONa]} = K_a \times \frac{\text{moles } CH_3COOH}{\text{moles } CH_3COONa}$

moles CH_3COOH = 0.750 L x 0.64 mole/L = 0.480

moles CH_3COONa = 75.0 g x $\frac{1 \text{ mole}}{82.0 \text{ g}}$ = 0.915

$[H^+] = 1.8 \times 10^{-5} \times \frac{0.480}{0.915} = 9.44 \times 10^{-6}$ pH = 5.0

9. $[H^+] = K_a \times \frac{\text{moles } CH_3COOH}{\text{moles } CH_3COONa}$ pH = 6.0 $[H^+] = 1.0 \times 10^{-6}$

moles CH_3COOH = 0.0500 L x 0.50 mole/L = 0.025

$$1.0 \times 10^{-6} = 1.8 \times 10^{-5} \times \frac{0.025}{\text{moles } CH_3COONa}$$

$$\text{moles } CH_3COONa = \frac{1.8 \times 10^{-5} \times 0.025}{1.0 \times 10^{-6}} = 0.45$$

mass CH_3COONa = 0.45 mole x 82.0 g/mole = 37 g

10. $NaOH + HF \rightarrow NaF + H_2O$

moles NaOH = 0.0172 L x 0.155 mole/L = 2.67×10^{-3}

moles HF = 0.0250 L x 0.200 mole/L = 5.00×10^{-3}

moles NaF formed = 2.67×10^{-3}

moles HF left over = (5.00 - 2.67) x 10^{-3} = 2.33×10^{-3}

A solution of NaF and HF is a buffer solution

$$[H^+] = K_a \times \frac{[HF]}{[NaF]} = K_a \times \frac{\text{moles HF}}{\text{moles NaF}} = 7.2 \times 10^{-4} \times \frac{2.33 \times 10^{-3}}{2.67 \times 10^{-3}}$$

$= 6.28 \times 10^{-4}$ pH = 3.2