Answers to Chapters 15 & 16 Study Questions

1. a) strong acid + strong base: steepest at equivalence, low pH at start depending on concentration of acid, equivalence at pH 7, no buffering.
   b) weak acid + strong base: less steep at equivalence than strong acid, low pH at start depending on K_a and concentration of acid, equivalence at basic pH, buffering.
   c) weak base + strong acid: less steep at equivalence than strong base, high pH at start depending on K_b and concentration of base, equivalence at acid pH, buffering.

2. a) blue b) pH = 5
   c) an indicator changes color when [HA] = [A⁻] and $[H^+] = K_a$;
   therefore $K_a = [H^+] = 10^{-3.5} = 3.2 \times 10^{-4}$
   d) weak base + strong acid → weak acid; acid endpoint; methyl red

3. $V_A \times M_A = V_B \times M_B$; $V_A \times 2.00$ M = 12.5 mL × 0.800 M; V_A = **0.500 mL**
   (optional pH of solution:) $H^+ + NH_3 \rightarrow NH_4^+$; final volume = 12.5 + .5 = 13.0 mL
   Final $[NH_4^+]$: 12.5 mL × 0.0800 M = 13.0 mL × M_2; M_2 = 0.0769 M NH_4^+ at end.
   So, calculate the pH of 0.0769 M NH_4^+:
   $K_a = \frac{[H^+]\times[NH_3]}{[NH_4^+]}$; $5.6\times10^{-10} = \frac{x^2}{0.769\ M}$; $x^2 = (5.6 \text{ x } 10^{-10})(0.0769) = 4.3 \text{ x } 10^{-11}$;
   $x = (4.3 \times 10^{-11})^{½} = 6.6 \times 10^{-6}$ M; pH = − log (6.6×10^{-6} M) = **5.2**
   (you get the same answer if you used 0.080 M NH_4^+.)

4. a) $K_a(CH_3COOH) = 1.8 \times 10^{-5}$; $[H^+] = 1.0 \text{ x } 10^{-5}$ M
   $$\frac{[CH_3COO^-]}{[CH_3COOH]} = \frac{K_a}{[H^+]} = \frac{1.8\times10^{-5}}{1.0\times10^{-5}} = \mathbf{1.8}$$
   b) Mix the solutions in a 1.8: 1 ratio. For example, mix 180. mL of 0.100 M $NaCH_3COO$ with 100 mL 0.100 M CH_3COOH.
   c) Mix 280 mL 0.100 M CH_3COOH and 180. mL 0.100 M NaOH.
   d) Another pH 5.00 buffer might be $Al(H_2O)_6^{3+}$ or even benzoic acid.

5. a) limiting reactant problem: 0.750 L × 0.400 M NaOH = 0.300 moles OH^-
   0.250 L × 0.800 M HCl = 0.200 mol H^+.
   0.300 moles OH^- + 0.200 mol H^+ → 0.200 mol H_2O + 0.100 mol OH^- remain.
   Total volume = 250 mL + 750 mL = 1.00 liter.
   $[OH^-] = \frac{0.100\ mol}{1\ liter}$ = 0.100 M; pOH = 1.0; pH = **13.0**
   b) $pH = pK_a + \log\frac{[HCO_3^-]}{[H_2CO_3]}$; $pK_a = -\log(4.4\times10^{-7}) = 6.36$

$$pH = 6.36 + \log\left(\frac{1}{2}\right) = 6.36 - 0.30 = \mathbf{6.06}$$

6. $MgCl_2 \rightleftarrows Mg^{2+}(aq) + 2\ Cl^-(aq)$; $K_{sp} = [Mg^{2+}] \times [Cl^-]^2$

$$[MgCl_2] = \frac{8.0\ g\ MgCl_2}{108\ g\ solution} \times \frac{1\ g\ solution}{1\ mL\ solution} \times \frac{1000\ mL}{1\ L} \times \frac{1\ mol\ MgCl_2}{95.2\ g\ MgCl_2} = 0.778\ M$$

0.778 M $MgCl_2$: $[Mg^{2+}] = 0.778$ M; $[Cl^-] = 2(0.778\ M) = 1.56$ M

$K_{sp} = [Mg^{2+}] \times [Cl^-]^2 = (0.778) \times (1.56)^2 =$ **1.88**

7. $CuCrO_4 \rightleftarrows Cu^{2+}(aq) + CrO_4^{2-}(aq)$; $K_{sp} = [Cu^{2+}] \times [CrO_4^{2-}] = 3.6 \times 10^{-6}$;

$x = [CuCrO_4] = [Cu^{2+}] = [CrO_4^{2-}]$; $K_{sp} = 3.6 \times 10^{-6} = x^2$

$x = (3.6 \times 10^{-6})^{½} =$ **1.9×10^{-3} M**

8. $2\ AgNO_3(aq) + Na_2CO_3(aq) \rightarrow 2\ NaNO_3(aq) + Ag_2CO_3(s)$

$Ag_2CO_3(s) \rightleftarrows 2\ Ag^+(aq) + CO_3^{2-}(aq)$; $K_{sp} = [Ag^+]^2 \times [CO_3^{2-}] = 8.1 \times 10^{-12}$

$x = [Ag^+]$; $[CO_3^{2-}] = 0.020$ M; $K_{sp} = x^2(0.020) = 8.1 \times 10^{-12}$

$x^2 = \frac{8.1 \times 10^{-12}}{0.020} = 4.1 \times 10^{-10}$; $x = (4.1 \times 10^{-10})^{½} =$ **2.0×10^{-5} M**

9. $Pb(NO_3)_2(aq) + 2\ NaBr(aq) \rightarrow 2\ NaNO_3(aq) + PbBr_2(s)$.

$PbBr_2(s) \rightleftarrows Pb^{2+}(aq) + 2\ Br^-(aq)$; $K_{sp} = [Pb^{2+}] \times [Br^-]^2$; $K_{sp} = 4.6 \times 10^{-6}$

When solutions are mixed in a 1:1 ratio, each is diluted by a factor of 2.

$[Pb^{2+}] = (0.0100\ M)/2 = 0.00500$ M; $[Br^-] = (0.0200\ M)/2 = 0.0100$ M

$Q = [Pb^{2+}] \times [Br^-]^2 = (0.00500) \times (0.0100)^2 = 5.0 \times 10^{-7}$

$5.0 \times 10^{-7} < 4.6 \times 10^{-6}$; $Q < K_{sp}$; **therefore, no precipitate forms**

10. a) strong acid reacts with the weak acid in the buffer:

$H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq)$

b) $Ag_3PO_4(s) \rightleftarrows 3\ Ag^+(aq) + PO_4^{3-}(aq)$; $K_{sp} = [Ag^+]^3 \times [PO_4^{2-}]$

11. molar mass = mass/moles;

moles acid = moles base: $17.5\ mL \times \frac{0.268\ mol\ NaOH}{1000\ mL} = 0.00469$ moles acid

molar mass $= \frac{0.422\ g}{.00469\ moles} =$ **90.0 g/mol**