

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 \rightarrow weak acid; acid endpoint; methyl red
3. $V_A \times M_A = V_B \times M_B$; $V_A \times 2.00 \text{ M} = 12.5 \text{ mL} \times 0.800 \text{ M}$; $V_A = \mathbf{0.500 \text{ mL}}$
 (optional pH of solution:) $H^+ + NH_3 \rightarrow NH_4^+$; final volume = $12.5 + .5 = 13.0 \text{ mL}$
 Final $[NH_4^+]$: $12.5 \text{ mL} \times 0.0800 \text{ M} = 13.0 \text{ mL} \times M_2$; $M_2 = 0.0769 \text{ M } NH_4^+$ at end.
 So, calculate the pH of $0.0769 \text{ M } NH_4^+$:

$$K_a = \frac{[H^+] \times [NH_3]}{[NH_4^+]}$$
; $5.6 \times 10^{-10} = \frac{x^2}{0.769 \text{ M}}$; $x^2 = (5.6 \times 10^{-10})(0.0769) = 4.3 \times 10^{-11}$;
 $x = (4.3 \times 10^{-11})^{1/2} = 6.6 \times 10^{-6} \text{ M}$; $pH = -\log(6.6 \times 10^{-6} \text{ M}) = \mathbf{5.2}$
 (you get the same answer if you used $0.080 \text{ M } NH_4^+$.)
4. a) $K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$; $[H^+] = 1.0 \times 10^{-5} \text{ M}$

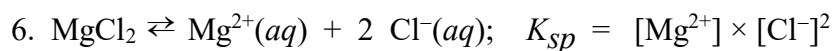
$$\frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} = \frac{K_a}{[H^+]} = \frac{1.8 \times 10^{-5}}{1.0 \times 10^{-5}} = \mathbf{1.8}$$

 b) Mix the solutions in a 1.8: 1 ratio. For example, mix 180. mL of $0.100 \text{ M } \text{NaCH}_3\text{COO}$ with 100 mL $0.100 \text{ M } \text{CH}_3\text{COOH}$.
 c) Mix 280 mL $0.100 \text{ M } \text{CH}_3\text{COOH}$ and 180. mL $0.100 \text{ M } \text{NaOH}$.
 d) Another pH 5.00 buffer might be $\text{Al}(\text{H}_2\text{O})_6^{3+}$ or even benzoic acid.
5. a) limiting reactant problem: $0.750 \text{ L} \times 0.400 \text{ M } \text{NaOH} = 0.300 \text{ moles } \text{OH}^-$
 $0.250 \text{ L} \times 0.800 \text{ M } \text{HCl} = 0.200 \text{ mol } \text{H}^+$
 $0.300 \text{ moles } \text{OH}^- + 0.200 \text{ mol } \text{H}^+ \rightarrow 0.200 \text{ mol } \text{H}_2\text{O} + 0.100 \text{ mol } \text{OH}^- \text{ remain.}$
 Total volume = $250 \text{ mL} + 750 \text{ mL} = 1.00 \text{ liter.}$

$$[\text{OH}^-] = \frac{0.100 \text{ mol}}{1 \text{ liter}} = 0.100 \text{ M}; p\text{OH} = 1.0; \text{pH} = \mathbf{13.0}$$

 b) $pH = pK_a + \log \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$; $pK_a = -\log(4.4 \times 10^{-7}) = 6.36$

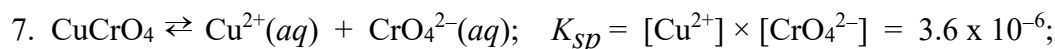
$$pH = 6.36 + \log\left(\frac{1}{2}\right) = 6.36 - 0.30 = \mathbf{6.06}$$



$$[\text{MgCl}_2] = \frac{8.0 \text{ g MgCl}_2}{108 \text{ g solution}} \times \frac{1 \text{ g solution}}{1 \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ mol MgCl}_2}{95.2 \text{ g MgCl}_2} = 0.778 \text{ M}$$

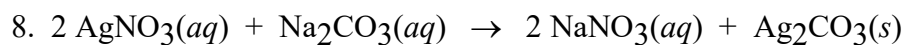
$$0.778 \text{ M MgCl}_2: [\text{Mg}^{2+}] = 0.778 \text{ M}; [\text{Cl}^{-}] = 2(0.778 \text{ M}) = 1.56 \text{ M}$$

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



$$x = [\text{CuCrO}_4] = [\text{Cu}^{2+}] = [\text{CrO}_4^{2-}]; K_{sp} = 3.6 \times 10^{-6} = x^2$$

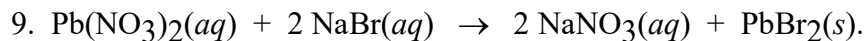
$$x = (3.6 \times 10^{-6})^{1/2} = \mathbf{1.9 \times 10^{-3} \text{ M}}$$



$$\text{Ag}_2\text{CO}_3(s) \rightleftharpoons 2 \text{Ag}^{+}(aq) + \text{CO}_3^{2-}(aq); K_{sp} = [\text{Ag}^{+}]^2 \times [\text{CO}_3^{2-}] = 8.1 \times 10^{-12}$$

$$x = [\text{Ag}^{+}]; [\text{CO}_3^{2-}] = 0.020 \text{ M}; K_{sp} = x^2(0.020) = 8.1 \times 10^{-12}$$

$$x^2 = \frac{8.1 \times 10^{-12}}{0.020} = 4.1 \times 10^{-10}; x = (4.1 \times 10^{-10})^{1/2} = \mathbf{2.0 \times 10^{-5} \text{ M}}$$



$$\text{PbBr}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2 \text{Br}^{-}(aq); K_{sp} = [\text{Pb}^{2+}] \times [\text{Br}^{-}]^2; K_{sp} = 4.6 \times 10^{-6}$$

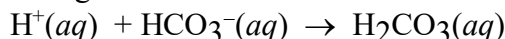
When solutions are mixed in a 1:1 ratio, each is diluted by a factor of 2.

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

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

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

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



11. molar mass = mass/moles;

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

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