CH 302 Spring 2007 Worksheet 6 Key

1. You have a 750 mL solution of 0.1 M methylamine. You can't find the K_b for methylamine but notice that the K_a for its conjugate acid is 1×10^{-9}. What is the pH of the methylamine solution?

   Answer: $K_w = K_a K_b = 1 \times 10^{-14}$ so $K_b = 1 \times 10^{-5}$
   $[OH^-] = (K_b C_b)^{1/2} = [(0.1)(10^{-5})]^{1/2} = 10^{-3}$
   pOH = 3 pH = 14-pOH = **11**

2. You decide to titrate it against 1 M hydrochloric acid. When you've added 25 mL of the HCl to the solution, what is the pH?

   Answer: You have 0.075 mol ammonia and 0.025 mol HCl. Neutralize:
   You end up with 0.05 mol ammonia and 0.025 mol ammonium ion (NH_4^+). This is a buffer.
   $[OH^-] = K_b(C_b/C_a) = 10^{-5}(0.05/0.025) = 2 \times 10^{-5}$
   $pOH = -\log(2 \times 10^{-5}) = 4.7$ pH = 14-4.7 = **9.3**

3. You continue the titration. What is the pH when you've added 75 mL HCl total? What is this point called?

   Answer: You have 0.075 mol of each. Neutralize: You end up with 0.075 mol of ammonium ion. This is a weak acid.
   $[H^+] = (K_a C_a)^{1/2}$
   Remember $Ka = Kw/Kb = 10^{-14}/10^{-5} = 10^{-9}$
   Also remember that the total volume is 75 mL + 750 mL = 775 mL
   $[H^+] = [(10^{-9})(0.075 \text{ mol}/0.775 \text{ L})]^{1/2} = 9.8 \times 10^{-6}$ M
   $pH = -\log(9.8 \times 10^{-6}) =$ **5.0**

4. You keep going until you've added 100 mL HCl. What is this final pH?

Answer: You have 0.075 mol ammonia and 0.1 mol HCl. Neutralize: You end up with 0.025 mol H+ and 0.075 mol ammonium ion. The ammonium ions are weak; ignore them. This is a strong acid solution.
$[H^+] = C_a = 0.025 \text{ mol}/(0.850 \text{ L}) = 0.029$ M
$pH = -\log(0.029 \text{ M}) =$ **1.5**

5. AgCl has a K_{sp} of 1.77×10^{-10}. What is the molar solubility of AgCl?

   Answer: $K_{sp} = x^2$
   $x = (K_{sp})^{1/2} = (1.77 \times 10^{-10})^{1/2} = \mathbf{1.33 \times 10^{-5}}$

6. $Mg_3(PO_4)_2$ has a K_{sp} of 9.86×10^{-25}. What is the molar solubility of $Mg_3(PO_4)_2$?

   Answer: $K_{sp} = (3x)^3(2x)^2 = 10x^5$
   $x = (K_{sp}/108)^{1/5} = (9.86 \times 10^{-25}/108)^{1/5} = \mathbf{6.20 \times 10^{-6}}$

7. Given the following compounds and K_{sp} values, rank the compounds from most to least soluble.

Compound	K_{sp}	Molar solubility	Rank
ZnS	2.0×10^{-25}	4.5 x 10-13	2
Ag_2S	1.0×10^{-49}	2.9 x 10-17	3

$Fe(OH)_3$	6.3×10^{-38}	2.9 x 10-10	1
Fe_2S_3	1.4×10^{-88}	1.1 x 10-18	4

8. You drop 0.1 g of solid NaOH in an Olympic-sized swimming pool full of pure water (volume = 2.5×10^6 L). What is the pH of the pool?

Answer: Calculate Cb

$C_b = (0.1\ g / (40\ g/mol))/(2.5 \times 10^6\ L) = 10^{-9}$ M

If we use our approximation,

$[OH^-] = C_b = 10^{-9}$

But water contributes 100 times this much, so we can't ignore it.

$[OH^-] = 10^{-9} + 10^{-7} = 1.01 \times 10^{-7}$

$pOH = -\log(1.01 \times 10^{-7}) = 6.996$ **pH = 7.004**

(Or, **pH ≈ 7**)

9. What if you'd dropped 10 kg of NaOH into the pool?

Answer: You drop in 100,000 times as much NaOH, C_b is 100,000 times larger.

$C_b = 10^{-4}$ M

Now our approximation holds.

$[OH^-] = 10^{-4}$ M

pOH = 4 **pH = 10**

10. List the assumptions that must be true for us to obtain reasonably accurate answers when using equations like $[H^+] = C_a$ or $[OH^-] = (K_bC_b)^{0.5}$.

Answer: Ks are far apart—with respect to K_w it means the K_a or K_b is 1×10^{-10} or larger

C is large enough—with respect to water they are values greater than 10^{-5}

11. Briefly explain the major reason that any of the above assumptions being false would invalidate our approximations.

Answer: In either case, it means that the contribution of H+ or OH- from other species in solution is non-negligible. With respect to water it means that 10^{-7} M H^+ or OH^- is at least 1% of the contribution to total.

12. You have a neutralization reaction, $OH^- + HA \leftrightarrow H_2O + A^-$. Given the following starting concentrations of OH^- and HA, give the end concentrations of OH^-, HA, and A^-.

a. Initial: $[OH^-]$ = 0.1 M [HA] = 1 M
   Final: $[OH^-]$ = 0 M [HA] = 0.9 M $[A^-]$ = 0.1 M
b. Initial: $[OH^-]$ = 1 M [HA] = 1 M
   Final: $[OH^-]$ = 0 M [HA] = 0 M $[A^-]$ = 1 M
c. Initial: $[OH^-]$ = 1 M [HA] = 0.1 M
   Final: $[OH^-]$ = 0.9 M [HA] = 0 M $[A^-]$ = 0.1 M

Answer: Simple limiting reagent stuff. In a, OH- is the limiting reagent, in b, there is no limiting reagent (or both are, however you want to look at it), and in c, HA is the limiting reagent.

13-19. State whether the given mixture forms a buffer (hint: you may have to neutralize first). Whether it does or not, calculate the pH. K_a for HCOOH = 10^{-5}.

13. 1 M HCOOH and 1 M $COOH^-$

Answer: This is the definition of a buffer.

$[H^+] = K_a(C_a/C_b) = 10^{-5}(1/1) = 10^{-5}$

pH = 5

14. 1 M HCOOH and 1 M NaOH

Answer: Neutralize. You end up with 1 M $COOH^-$. This is not a buffer. It's a weak base.

$[OH^-] = (K_bC_b)^{1/2} = [(10^{-14}/10^{-5})(1)]^{1/2}$

$= [10^{-9}]^{1/2} = 10^{-4.5}$

pOH = 4.5 **pH = 9.5**

15. 1 M HCOOH and 0.5 M NaOH

Answer: Neutralize. You end up with 0.5 M HCOOH and 0.5 M $COOH^-$. This is a buffer. Notice that C_a/C_b is the same as in #13; so **pH = 5**.

16. 1 M HCl and 1 M HCOOH

Answer: This is a strong and a weak acid. This isn't a buffer. The weak acid doesn't matter.

$[H^+] = C_a = 1$ M

pH = 0

17. 1 M HCl and 1 M $COOH^-$

Answer: Neutralize. You end up with 1 M HCOOH. This isn't a buffer, it's a weak acid.

$[H^+] = (K_aC_a)^{1/2} = [(10^{-5})(1)]^{1/2} = 10^{-2.5}$

pH = 2.5

18. 1 M HCl and 5 M $COOH^-$

Answer: Neutralize. You end up with 4 M COOH- and 1 M HCOOH. This is a buffer.

$[H^+] = K_a(C_a/C_b) = 10^{-5}(1/4) = 2.5 \times 10^{-6}$

pH = $-\log(2.5 \times 10^{-6})$ = **5.6**

19. 1 M HCl and 0.5 M $COOH^-$

Answer: Neutralize. You end up with 0.5 M HCl and 0.5 M HCOOH. This is a strong acid/weak acid, not a buffer.

[H+] = Ca = 0.5 M

pH = -log(0.5) = **0.3**

20. Write down the five types of neutralization reactions form MEMORY

Answer:

$H^+ + OH^- \leftrightarrow H_2O$

$HA + OH^- \leftrightarrow H_2O + A^-$

$HB^+ + OH^- \leftrightarrow H_2O + B$

$B + H^+ \leftrightarrow BH^+$ (or $B + H_3O^+ \leftrightarrow BH^+ + H_2O$)

$A^- + H+ \leftrightarrow HA$ (or $A^- + H_3O^+ \leftrightarrow HA + H_2O$)