CH302 Spring 2008 Worksheet 5

20 questions involving simple water equilbria and the approximations that make them simple.

1. The only water equilibrium for which we make no approximations is the case of pure water (amazing how simple something is when you don't add anything to it.) What is the most common approximation made when we add acids or bases to water?

2. For each of the compounds and concentrations shown below, tell what kind of compound it is (strong acid, weak acid, strong base, weak base, salt) and write down the equation you would use to solve the problem.

compound	type	equation
0.2 M $HClO_4$		
0.1 M NH_4Cl		
HgI_2		
0.03 M $Ba(OH)_2$		
0.2 M CH_3NH_2		
0.2 M lithium acetate		
0.1 M lactic acid		
AgI		

3-11. For the next eight problems, find either the pH or the molar solubility of the compound for the compounds in Table 2. Assume a simple equilibrium in each case. You will note that the total time and uncertainty involved in solving these eight problems will probably be less than the time and doubt involved in completing table 2. This should be a heads up to you that the biggest reason people struggle in this section of material is that they don't know what kind of problem they are working—and we haven't even started dumping multiple compounds into solution!!

3. What is the pH of 0.2 M $HClO_4$?

4. What is the pH of 0.1 M NH_4Cl? The pK_b of NH_3 is 4.75.

5. What is the molar solubility of HgI_2? The K_{sp} of HgI_2 is 3×10^{-29}.

6. What is the pH of 0.03 M $Ba(OH)_2$? (Hint, there are 2 OH^- dumped into solution for each $Ba(OH)_2$.)

7. What is the pH of 0.2 M CH_3NH_2 if the pK_b is 3.8?

8. What is the pH of 0.2 M $HClO_4$?

9. What is the pH of 0.2 M lithium acetate if the pK_b is 9.3?

10. What is the pH of 0.1 M lactic acid if the K_a is 1.4×10^{-4}?

11. What is the molar solubility of 0.1 M AgI if the K_{sp} ia 8.3 a 10^{-17}?

12. Dr. Laude walks into class every day during the sections on water equilibria and wastes a lot of tape putting the following simple symbols for acids and bases on the board. Then he rants that no matter how complicated an acid or base is, it can be simplified to one of these six forms.

H^+ HA BH^+ B A^- OH^-

Many of you will not think it is necessary to learn this simple notation, but that is because we haven't dealt with buffers and neutralizations yet. So for the mean time, humor Dr. Laude by learning what the symbols mean and finding an example of each of these symbols in question 2.

One example is provided to get you started.

abbreviation	type	example	equation
H^+			
HA			
BH^+			
B			
A^-	charged weak base	0.2 M lithium acetate	$[OH^-] = (K_bC_b)^{0.5}$
OH^-			

13. Remember how much fun it was to take IQ tests as a child, back when you thought you were a genius? One type of problem that you no doubt saw was a series of symbols in which you had to figure out the next one in the pattern. Here is one that is relevant to this course:

$1x^2$ $4x^3$ $27x^4$??? ← what is next in the series and what salt does it describe?

By the way, as you figure it out, I hope you realize that this is the pattern for the simple relationship between K_{sp} values and molar solubilties you would find from the RICE expression..

14. The mathematically inclined might want to write down the general solution for the pattern in problem 13.

15. You may notice that there is a nice approximation you can use for finding the molar solubilities for a given salt: the molar solubility is approximately the root of the number of ions in solution. For example:

- AgCl puts two ions in solution and the molar solubility is approximately the square root of the K_{sp}.
- $CuCl_2$ puts three ions in solution and the molar solubility is approximately the cubed root of the K_{sp}.
- $AuCl_3$ puts four ions in solution and the molar solubility is approximately the fourth root of the K_{sp}.

Given this handy trick, what are the approximate solubilities of the following fake salts and their Ksp values. Please don't use a calculator.

AB $K_{sp} = 1 \times 10^{-60}$ Molar solubility is approximately ________________
AB_2 $K_{sp} = 1 \times 10^{-60}$ Molar solubility is approximately ________________
AB_3 $K_{sp} = 1 \times 10^{-60}$ Molar solubility is approximately ________________
A_2B_3 $K_{sp} = 1 \times 10^{-60}$ Molar solubility is approximately ________________

16. Use the approximation you learned in problem 15 above to solve the following problem in just a few seconds without using a calculator. Rank the solubilities of the following compounds from least soluble to most soluble. (Hint: unlike ranking weak acids and bases, the size of the K is not all you have to consider.)

abbreviation	type	Solubility rank
AB	$K_{sp} = 1 \times 10^{-30}$	
AB_2	$K_{sp} = 1 \times 10^{-50}$	
AB_3	$K_{sp} = 1 \times 10^{-90}$	
A_2B_3	$K_{sp} = 1 \times 10^{-60}$	

Enough on equations of simple (single compound) equilibria. Not it is time to think about approximations that make simple equilibrium equations possible.

17. Derive the weak acid equation ($[H^+] = (K_aC_a)^{0.5}$) by placing C_a for the concentration of weak acid into the RICE expression and solving:

R	HA →	H^+ +	A^-
I	C_a		
C			
E			

18. During the derivation in problem 17 you made two approximations. In which boxes of the RICE expression did these approximations occur and what were the approximations? Can you suggest a general rule for when the approximations will hold based upon Dr. Laude's notion that 1% error is permissible?

19. For the various combinations of weak acid K_a and concentrations shown below, indicate the ones that can be solved using the equation $[H^+] = (K_aC_a)^{0.5}$ because the approximations we made in the derivation hold. If you can't use the approximation, explain why. (Note, you won't circle very many, which tells you how careful we have to be teaching freshman chemistry to make sure our questions are just right.)

acid	Ka	concentration	Reason $[H^+] = (K_aC_a)^{0.5}$ doesn't work
chlorous acid	1.2×10^{-2}	1 M	
chlorous acid	1.2×10^{-2}	1×10^{-2} M	
chlorous acid	1.2×10^{-2}	1×10^{-7} M	Doesn't work, K is too large and [ ] is too dilute
formic acid	1.8×10^{-4}	1 M	
formic acid	1.8×10^{-4}	1×10^{-2} M	Can be solved with $[H^+] = (K_aC_a)^{0.5}$
formic acid	1.8×10^{-4}	1×10^{-7} M	
Hydrocyanic acid	5×10^{-10}	1 M	
Hydrocyanic acid	5×10^{-10}	1×10^{-7} M	
hydrogen peroxide	2.4×10^{-12}	1M	

20. What is the pH of 2.4×10^{-8} M HNO_3? Hint: if you get a pH greater than 7 for a strong acid it will make your professor very sad.