CH302 Worksheet 5 Answer Key: A charming calculator-free worksheet concerning K_{sp}, K_w, K_a & K_b and strong acids and bases.

1. Define K_{sp} for the dissolution of the following salts in water. If necessary, write a balanced chemical equation for the dissolution first.
   a. RbI, $RbI(s) \leftrightarrows Rb^+(aq) + I^-(aq)$, $K_{sp} = [Rb^+]\cdot[I^-]$
   b. $Ca(NO_3)_2$, $K_{sp} = [Ca^{2+}]\cdot[NO_3^-]^2$
   c. K_3PO_4, $K_{sp} = [K^+]^3\cdot[PO_4^{3-}]$
   d. SrS, $K_{sp} = [Sr^{2+}]\cdot[S^{2-}]$
   e. $Fe_2(SO_4)_3$, $K_{sp} = [Fe^{3+}]^2\cdot[SO_4^{2-}]^3$
   f. $K_3Fe(C_2O_4)_3$, $K_{sp} = [K^+]^3\cdot[Fe^{3+}]\cdot[C_2O_4^{2-}]^3$

2. Consider each of the salts below. Express each salt's molar solubility (we'll call it x) in terms of K_{sp}. It might be useful to first write a balanced equation for each salt's dissolution and complete a RICE diagram.
   a. $Cu_3(PO_4)_2$, molar solubility = x = $(K_{sp}/108)^{1/5}$

R	$Cu_3(PO_4)_2(s)$	$\leftrightarrows$	$3\ Cu^{2+}(aq)$	+	$2\ PO_4^{3-}(aq)$
I	~		0		0
C	~		+ 3x		+2x
E	~		3x		2x

$K_{sp} = [Cu^{2+}]^3\cdot[PO_4^{3-}]^2 = (3x)^3\cdot(2x)^2 = 108x^5$
$K_{sp} = 108x^5$
$x = (K_{sp}/108)^{1/5}$
   b. MgSe, $x = (K_{sp})^{1/2}$
   c. Li_3PO_4, $x = (K_{sp}/27)^{1/4}$
   d. $K_3Fe(C_2O_4)_3$, $x = (K_{sp}/729)^{1/7}$

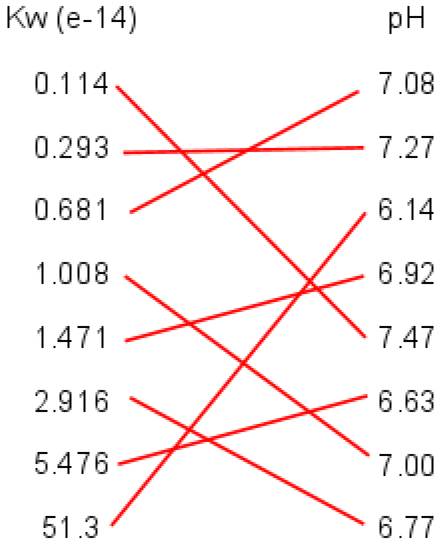
3. Estimate the actual molar solubilities of the following salts in water based on their K_{sp} values.
   a. Barium Sulfate, $BaSO_4$, $K_{sp} = 1.08\ x10^{-10}$, molar solubility = $x \cong 10^{-5}$ M
   b. Cadmium Phosphate, $Cd_3(PO_4)_2$, $K_{sp} = 2.53\ x10^{-33}$, $x \cong 10^{-6}$ M
   c. Lithium Carbonate, Li_2CO_3, $K_{sp} = 1.73\ x10^{-3}$, $x \cong 10^{-1}$ M
   d. Magnesium Ammonium Phosphate, $MgNH_4PO_4$, $K_{sp} = 2.5\ x10^{-13}$, $x \cong 10^{-4}$ M

4. Estimate the actual molar solubilities of the following salts in the following solutions based on the provided concentrations and Ksp values. It might be useful to first write a balanced equation for each salt's dissolution and complete a RICE diagram.
   a. Mercuric Bromide, $HgBr_2$, $K_{sp} = 8\ x10^{-20}$, in 2 M $Hg(NO_3)_2$, molar solubility = x = 10^{-10} M

R	$HgBr_2(s)$	$\leftrightarrows$	$Hg^{2+}(aq)$	+	$Br^-(aq)$
I	~		2		0
C	~		+ x		+2x
E	~		2 + 3x		2x

$K_{sp} = [Hg^{2+}]\cdot[Br^-]^2$
$8\ x10^{-20} = (2 + 3x)\cdot(2x)^2$
For the term (2 + 3x), it is safe to assume that $2 + 3x \cong 2$, and the equation reduces to
$8\ x10^{-20} = (2)\cdot(2x)^2$
$x = (8\ x10^{-20}/8)^{1/2} = 10^{-10}$ M
   b. Silver Chloride, AgCl, $K_{sp} = 1.56\ x10^{-10}$, in 15 M KCl, $x = 10^{-11}$ M
   c. Barium Iodate, $Ba(IO_3)_2$, $K_{sp} = 6.5\ x10^{-10}$, in 2.5 M KIO_3, $x = 10^{-10}$ M

5. Match the K_W values on the left with their corresponding pH values on the right. Assume you have a sample of completely pure water.



6. Answer the following questions concerning the autoprotolysis of water;

   a. Is the autoprotolysis of water endothermic or exothermic?
      endothermic

   b. What would be a simple experiment to verify this?
      Measuring the pH of a sample of pure water at different temperatures - pH will be inversely proportional to temperature if autoprotolysis is endothermic.

   c. What would be a simple way to calculate $\Delta H_{autoprotolysis}$?
      Similar to above, measureing pH at a range of temperatures would enable us to compute K_W at those temperatures and we could then use the van't Hoff equation.

7. List the 7 strong acids from memory.
Hydrochloric (HCl), Hydrobromic (HBr), Hydroiodic (HI), Sulfuric (H_2SO_4), Nitric (HNO_3), Chloric ($HClO_3$) and Perchloric ($HClO_4$)

8. List the 8 strong bases from memory.
Lithium Hydroxide (LiOH), Sodium Hydroxide (NaOH), Potassium Hydroxide (KOH), Rubidium Hydroxide (RbOH), Cesium Hydroxide (CsOH), Calcium Hydroxide [$Ca(OH)_2$], Strontium Hydroxide [$Sr(OH)_2$], Barium Hydroxide [$Ba(OH)_2$]

9. List the 14 spectator ions from memory. The answers to questions 7 and 8 are a **really** good starting point for this problem.
Chloride (Cl-), Bromide (Br-), Iodide (I-), Nitrate (NO_3^-), Chlorate (ClO_3^-), Perchlorate (ClO_4^-), Lithium ion (Li^+), Sodium ion (Na^+), Potassium ion (K^+), Rubidium ion (Rb^+), Cesium ion (Ce^+), Calcium ion (Ca^{2+}), Strontium ion (Sr^{2+}), Barium ion (Ba^{2+})

10. Decide whether each of the species below is a weak acid or weak base. Note that it is possible to know this based on a chemical's name, and generally possible based on its formula.

   a. pyridinium, weak acid
   b. oxalate, weak base
   c. HIO_3, weak acid
   d. NH_3, weak base

e. formic acid, weak acid
f. hydrazine, weak base
g ClO^-, weak base
h. NH^{4+}, weak acid

11. Complete the following table: (Hint: -log 0.4 = 0.4, this is a good and easy reference point to remember for the log function.)

	$[H^+]$ (M)	pH	$[OH^-]$ (M)	pOH
Solution A	0.4	0.4	2.5×10^{-14}	13.6
Solution B	1	0	10^{-14}	14
Solution C	10^{-13}	13	0.1	1
Solution D	0.01	2	10^{-12}	12
Solution E	10^{-15}	15	10	-1
Solution F	10^{-11}	11	0.001	3
Solution G	10^{-5}	5	10^{-9}	9
Solution H	2.5×10^{-14}	13.6	0.4	0.4
Solution I	10^{-7}	7	10^{-7}	7
Solution J	10^{-9}	9	10^{-5}	5

12. What would be the pH of the following solutions?
a. 0.01 M $HClO_4$, for a strong acid $[H^+] = C_a$, $-\log[H^+]$ = pH = 2
b. 0.05 M $Ba(OH)_2$, note that some strong bases yield 2 OH^-, pH = 13
c. 10 M HNO_3, pH = -1
d. 10 LiOH, pH = 15

13. What would be the pOH pf the following solutions?
a. 0.1 M RbOH, for a strong base $[OH^-] = C_b$, $-\log[OH^-]$ = pOH = 1
b. 0.5 M $Sr(OH)_2$, note that some strong bases yield 2 OH^-, pOH = 0
c. 0.001 M $HClO_3$, pOH = 11
d. 0.4 M HI, pOH = 13.6

14. What would be the pH of the following solutions? You may approximate if necessary; you should not need a calculator.
a. 0.25 M HNO_2, $K_a = 4.0 \times 10^{-4}$, for a weak acid $[H^+] = (K_a \cdot C_a)^{1/2}$, pH = 2
b. 5.55 M NH_3, $K_b = 1.8 \times 10^{-5}$, for a weak base $[OH^-] = (K_b \cdot C_b)^{1/2}$, pH = 12
c. 0.0125 M ascorbic acid, $K_a = 7.9 \times 10^{-5}$, pH = 3
d. 0.0135 M trimethylamine, $K_b = 7.4 \times 10^{-5}$, pH = 11
e. 0.3 M HOCl, $K_a = 3.5 \times 10^{-8}$, pH = 4

15. Consider each of the acids and bases below. Write the formula or name for each species' conjugate and calculate the K_a or K_b for that conjugate. Approximate if necessary.
a. ammonium, $K_a = 5.55 \times 10^{-10}$, ammonia, $K_b = 1.80 \times 10^{-5}$
b. OCl^-, $K_b = 2.5 \times 10^{-7}$, HOCl, $K_a = 4.0 \times 10^{-8}$
c. pyridine, $K_b = 1.6 \times 10^{-9}$, pyridinium, $K_a = 6.0 \times 10^{-6}$
d. HCN, $K_a = 4.0 \times 10^{-10}$, CN^-, $K_b = 2.5 \times 10^{-5}$