Week 9 KEY

1. Determine the molar solubility of copper (I) bromide in a 0.050 M solution of NaBr.

$CuBr_2 (s) \rightleftharpoons Cu^{+}(aq) + Br^{-}(aq)$

	$CuBr_2 (s)$	Cu^{+}	Br^{-}
I		0	.050
C		+ x	+ x
E		x	0.5 + x

$K_{sp} = [Cu^{+}][Br^{-}]$

$4.2 \times 10^{-8} = x(.05 + \cancel{x})$

assume negligible

$\frac{2x}{.5} \times 100$ ✓✓✓ passes

$\boxed{x = 8.4 \times 10^{-7}\ M}$

2. Calculate the molar solubility of strontium sulfate in
   a. pure water

$SrSO_4 (s) \rightleftharpoons Sr^{2+}(aq) + SO_4^{2-}(aq)$

	$SrSO_4 (s)$	Sr^{2+}	SO_4^{2-}
I		0	0
C		+ x	+ x
E		x	x

$K_{sp} = [Sr^{2+}][SO_4^{2-}]$

$2.8 \times 10^{-7} = x^2$

$\boxed{x = 5.29 \times 10^{-4}\ M}$

   b. in a 0.10 M solution of Na_2SO_4.

$SrSO_4 (s) \rightleftharpoons Sr^{2+}(aq) + SO_4^{2-}(aq)$

	$SrSO_4 (s)$	Sr^{2+}	SO_4^{2-}
I		0	0.1
C		+ x	+ x
E		x	0.1 + x

$K_{sp} = [Sr^{2+}][SO_4^{2-}]$

$2.8 \times 10^{-7} = x(.1 + \cancel{x})$

assume negligible

$\frac{x}{.1} \times 100$ ✓✓✓

passes

$\boxed{x = 2.8 \times 10^{-6}\ M}$

3. The molar solubility of $Ba(NO_3)_2$ in water is 0.105 mol/L. Determine the K_{sp}.

$$K_{sp} = [Ba^{2+}][NO_3^-]^2$$
$$= x(2x)^2$$
$$= 4x^3$$
$$= 4(0.105)^3$$
$$K_{sp} = 4.63 \times 10^{-3}$$

4. Write the dissociation reaction and K_{sp} expression for the following: $AlPO_4$, $BaSO_4$, CdS, and $Cu_3(PO_4)_2$

$AlPO_4\,(s) \rightleftharpoons Al^{3+}(aq) + PO_4^{3-}(aq)$ $\quad K_{sp} = [Al^{3+}][PO_4^{3-}]$

$BaSO_4\,(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$ $\quad K_{sp} = [Ba^{2+}][SO_4^{2-}]$

$CdS\,(s) \rightleftharpoons Cd^{2+}(aq) + S^{2-}(aq)$ $\quad K_{sp} = [Cd^{2+}][S^{2-}]$

$Cu_3(PO_4)_2\,(s) \rightleftharpoons 3Cu^{2+}(aq) + 2PO_4^{3-}(aq)$ $\quad K_{sp} = [Cu^{2+}]^3[PO_4^{3-}]^2$

Conceptual Problems:

5. Is a compound more or less soluble in a solution that contains a common ion?

less soluble, equillibrium shifts left

6. How does temperature affect solubility?

T ↑, solubility ↑

7. How would the addition of KOH affect the solubility of ammonium sulfate? How about the addition of HCl?

$(NH_4)_2SO_4\,(s) \rightleftharpoons 2NH_4^+(aq) + SO_4^{2-}(aq)$

$NH_4^+ + KOH \rightarrow NH_3$ $\qquad SO_4^{2-} + H^+ \rightarrow HSO_4^-$

both increase solubility by reacting with the product ions and shifting eq to the right.

8. You dissolve $Cu(OH)_2$ in each of the following aqueous solutions. What is the molar solubility in each?

   a. Solution buffered at pH 13 $[OH^-] = 0.1\ M$

$$Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$$

		Cu^{2+}	OH^-
I		0	0.1
C		+x	+2x
E		x	0.1 + 2x

$K_{sp} = [Cu^{2+}][OH^-]^2$

assume negligible

$\frac{2x}{0.1} \times 100$ ✓✓

$$2.2 \times 10^{-20} = x(0.1 + 2x)^2$$

$x = 2.2 \times 10^{-18}\ M$

   b. 0.2M copper (II) chloride

$$Cu(OH)_2 \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$$

		Cu^{2+}	OH^-
I		0.2	0
C		+x	+2x
E		.2 + x	2x

assume neg

$$2.2 \times 10^{-20} = (.2 + x)(2x)^2$$

$x = 1.1 \times 10^{-8}\ M$

9. Cadmium is a highly toxic environmental pollutant that enters wastewaters associated with zinc smelting (Cd and Zn commonly occur together in ZnS ores) and in some electroplating processes. One way of controlling cadmium in effluent streams is to add sodium hydroxide, which precipitates insoluble $Cd(OH)_2$. If 1000 L of a certain wastewater contains Cd^{2+} at a concentration of 1.6×10^{-5} M, what concentration of Cd^{2+} would remain after addition of 10 L of 4 <u>M</u> NaOH solution?

$Cd^{2+} = 1.6 \times 10^{-5}\ M \times 1000\ L = 0.016\ mol \div 1010\ L$

$OH^- = 4\ M \times 10\ L = 40\ mol \div 1010\ L$

$$Cd(OH)_2(s) \rightleftharpoons Cd^{2+}(aq) + 2OH^-(aq)$$

$K_{sp} = [Cd^{2+}][OH^-]^2$

		Cd^{2+}	OH^-
I		1.58×10^{-5}	0.04
C		$-x$	$-x$
E		$1.58 \times 10^{-5} - x$	$0.04 - x$

negative b/c we are shifting eq. towards the solid

$$2.54 \times 10^{-14} = (1.58 \times 10^{-5} - x)(.04 - x)^2$$

assume 0

$\therefore x \approx 1.58 \times 10^{-5}$

$\therefore x \approx$ ~~0.04~~

$[Cd^{2+}] = 1.58 \times 10^{-5} - x$

$\therefore Cd^{2+} \longrightarrow$ about zero

10. The molar solubility of calcium chloride at 35°C is 1.24×10^{-3} M. What is the K_{sp} at this temperature? What is the solubility (in g/L) in a 0.3M solution of magnesium chloride?

a. $K_{sp} = [Ca^{2+}][Cl^-]^2 = x(2x)^2 = 1.24 \times 10^{-3}$ M

$K_{sp} = 4(1.24 \times 10^{-3})^3 = 8.0 \times 10^{-9} = K_{sp}$

b. $CaCl_2(s) \rightleftharpoons Ca^{2+}(aq) + 2Cl^-(aq)$

	$CaCl_2$	Ca^{2+}	Cl^-
I		0	0.6
C		+x	+2x
E		x	0.6+2x

$\frac{2x}{0.6} \times 100$ ✓✓✓ passes

$8.0 \times 10^{-9} = x(.6 + \cancel{2x})^2$

$x = 2.2 \times 10^{-8}$ M

11. What is the pH of a 0.5 L solution made by mixing 1.0 moles of potassium acetate and 1.5 moles acetic acid? What is the pH of this solution if you add 5.0 mL 4.0 M HCl?

a. $HA + H_2O \rightleftharpoons A^- + H_3O^+$

	HA	H_2O	A^-	H_3O^+
I	3		2	0
C	−x		+x	+x
E	3−x		2+x	x

$K_a = \frac{[A^-][H_3O^+]}{[HA]}$

$1.8 \times 10^{-5} = \frac{x(2 \cancel{+x})}{(3 \cancel{+x})}$

assume neg

$\frac{x}{2} \times 100$ ✓✓✓ passes

$x = 2.7 \times 10^{-5}$

∴ pH = 4.57

b. $A^- + H^+ \rightarrow HA$

	A^-	H^+	HA
B	1.0	.02	1.5
R	−.02	−.02	+.02
A	0.98	—	1.52
C	1.94	—	3.01

$HA \rightleftharpoons A^- + H_3O^+$

	HA	A^-	H_3O^+
I	3.01	1.94	0
C	−x	+x	+x
E	3.01−x	1.94+x	x

assume neg

$1.8 \times 10^{-5} = \frac{x(1.94 \cancel{+x})}{3.01 \cancel{-x}}$

$\frac{x}{1.94} \times 100$ ✓✓✓ passes

$x = 2.74 \times 10^{-5}$

∴ pH = 4.56

12. Consider the titration of 50.0 mL of 0.200 M K_2SO_4 with 0.40 M HCl (aq)

a. What are the major species present before the addition of titrant?

K^+, SO_4^{2-}, H_2O

b. Calculate the pH at the equivalence point and identify the major species at this point?

$SO_4^{2-} + H^+ \rightarrow HSO_4^-$

	SO_4^{2-}	H^+	HSO_4^-	
B	.01	.01	0	
R	−.01	−.01	+.01	
A	—	—	.01	÷ 75mL
C	—	—	0.133	

$HSO_4^- + H_2O \rightleftharpoons SO_4^- + H_3O^+$

	HSO_4^-	H_2O	SO_4^-	H_3O^+
I	0.133		0	0
C	−x		+x	+x
E	.133−x		x	x

$1.2 \times 10^{-2} = x^2 / 0.133 - x$

$x = 0.0344$

$\therefore pH = 1.46$

MAJOR SPECIES:

K^+, HSO_4^-, H_2O

c. Calculate the pH at the halfway point and identify the major species at this point in the titration.

@ halfway point, pH = pKa

$\therefore pH = 3.38$

MAJOR SPECIES: H_2O, K^+, HSO_4^-, SO_4^{2-}

d. Calculate the pH 20.0 mL after the equivalence point and identify the major species at this point in the titration. 20.0 mL past eq = 45 mL added

$SO_4^{2-} + H^+ \rightarrow HSO_4^-$

	SO_4^{2-}	H^+	HSO_4^-	
B	.01	.018	0	
R	−.01	−.01	+.01	
A	—	.008	.01	÷ 95mL
C	—	.084	.105	

excess $[H^+]$ dominates

$pH = -\log(0.084)$

$\therefore pH = 1.08$

MAJOR SPECIES: H_2O, K^+, HSO_4^-, H^+

e. Which of the above point/points in the titration are buffered? Explain your answer.

part c (the halfway point) is buffered because both SO_4^{2-} and HSO_4^- are present.