AP CHEMISTRY

TOPIC 12: SOLUTIONS, PART A, EXAMPLES, PART II

Day 134:

- Solubility Equilibria
- Common Ion Effect

Example #1: Magnesium hydroxide dissociates in water according to the equation shown below.

$$Mg(OH)_2\,(s) \leftrightarrows Mg^{+2}\,(aq) + 2\,OH^{-1}\,(aq) \quad K_{sp} = 8.9 \times 10^{-12} \text{ at } 25^0C$$

a) Write the equilibrium expression:

$$K_{sp} = \left[Mg^{+2}\right]\left[OH^{-1}\right]^2$$

b) Calculate the concentration, in mol L^{-1} of $Mg^{+2}\,(aq)$ in a saturated solution of $Mg(OH)_2$ at 25^0C.

	$Mg(OH)_2$	$\rightleftharpoons$	Mg^{+2}	+	$2\,OH^{-1}$
I	-		0		0
C	-		$+x$		$+2x$
E	-		x		$2x$

$$K_{sp} = \left[Mg^{+2}\right]\left[OH^{-1}\right]^2 = 8.9\times10^{-12}$$

$$8.9\times10^{-12} = (x)(2x)^2 = 4x^3 \quad ; \quad \frac{8.9\times10^{-12}}{4} = x^3 = 2.225\times10^{-12}$$

$$x = \sqrt[3]{2.225\times10^{-12}} = 1.31\times10^{-4} = \left[Mg^{+2}\right] \; ; \; \left[OH^{-1}\right] = 2x = (2)(1.31\times10^{-4}) = 2.61\times10^{-4}$$

c) Calculate the maximum mass, in grams, of $Mg(OH)_2$ that can dissolve in 500 mL of water at 25^0C.

$$\frac{500\ mL}{}\times\frac{1\ L}{1000\ mL}\times\frac{1.31\times10^{-4}\ mol\ Mg^{+2}}{L}\times\frac{1\ mol\ Mg(OH)_2}{1\ mol\ Mg^{+2}}\times\frac{58.3158\ g}{1\ mol\ Mg(OH)_2} = 3.82\times10^{-3}\ g\ Mg(OH)_2$$

d) A 0.200 mol sample of solid $Mg(NO_3)_2$ is added to a 1.00 L saturated solution of $Mg(OH)_2$. Assuming no volume change, does [OH^{-1}] increase, decrease, or remain the same? Justify your answer.

According to Le Chatlier's principle, an increase in cations or anions will cause the reaction to shift away from those cations or anions. In this case, $MgNO_3$ will dissociate 100% (magnesium nitrate is a STRONG salt) causing an INCREASE in magnesium cations within the solution AT EQUILIBRIUM (be sure to say this part "at equilibrium). This addition of cations will cause the reaction to shift to the left forming more solid in the solution. Therefore, since the magnesium is being introduced into the solution the hydroxide ions (hydroxyl ions) will DECREASE from its original concentration at equilibrium. NO MATH is needed to answer this!

e) From part (d), after adding the 0.200 mol sample of solid $Mg(NO_3)_2$ which was added to a 1.00 L saturated solution of $Mg(OH)_2$. Assuming no volume change, does [NO_3^{-1}] increase, decrease, or remain the same? Justify your answer.

Great Question!!! Expect to see something like this on the AP EXAM !!! The nitrate ions WILL NOT CHANGE after they have been added to the solution at equilibrium. The solution does not care about nitrate – it is soluble with everything (that we care about).

Example #2: In a saturated solution of $Al(OH)_3$ at 25^0C, the concentration of Al^{+3} (*aq*) is 5.22 x 10^{-9} *M*. The equilibrium constant expression for the dissolving of $Al(OH)_3$ in water is shown below:

$$K_{sp} = [\ Al^{+3}\ ]\ [\ OH^{-1}\ ]^{-3}$$

a) Write the balanced equation for the dissolving of $Al(OH)_3$ in water.

$$Al\left(OH\right)_3 \ = \ Al^{+3} \ + \ 3\ OH^{-1}$$

b) Calculate the value of K_{sp} for $Al(OH)_3$ at 25^0C.

	$Al(OH)_3$	$\rightleftharpoons$	Al^{+3}	+	3 OH^{-1}
I	-		0		0
C	-		+ x		+ 3 x
E	-		5.22 x 10^{-9} M = x		3 x

$$Al^{+3} \ = \ 5.22\times10^{-9} \ = \ x$$

$$\left[OH^{-1}\right] \ = \ 3x \ = \ (3)\left(5.22\times10^{-9}\ M\right) \ = \ 1.57\times10^{-8}\ M$$

$$K_{sp} \ = \ \left[Al^{+3}\right]\left[OH^{-1}\right]^3 \ = \ \left(5.22\times10^{-9}\right)\left(1.57\times10^{-8}\right)^3 \ = \ 2.00\times10^{-32}$$

Example #3: In a saturated solution of $Cr_3(PO_4)_2$ at 25^0C, the concentration of Cr^{+2} (*aq*) is 3.42 x 10^{-7} *M*. The equilibrium constant expression for the dissolving of $Cr_3(PO_4)_2$ in water is shown below:

$$K_{sp} = [\ Cr^{+2}\ ]^3\ [\ PO_4^{-3}\ ]^2$$

a) Write the balanced equation for the dissolving of $Cr_3(PO_4)_2$ in water.

$$Cr_3\left(PO_4\right)_2 \ = \ 3\ Cr^{+2} \ + \ 2\ PO_4^{-3}$$

b) Calculate the value of K_{sp} for $Cr_3(PO_4)_2$ at 25^0C.

	$Cr_3(PO_4)_2$	$\rightleftharpoons$	3 Cr^{+2}	+	2 PO_4^{-3}
I	-		0		0
C	-		+ 3x		+ 2x
E	-		3.42 x 10^{-7} M = 3x		2x

$$Cr^{+2} \ = \ 3.42\times10^{-7} \ = \ 3x$$

$$x \ = \ \frac{3.42\times10^{-7}}{3} \ = \ 1.14\times10^{-7}$$

$$\left[PO_4^{-3}\right] \ = \ 2x \ = \ (2)\left(1.14\times10^{-7}\ M\right) \ = \ 2.28\times10^{-7}\ M$$

$$K_{sp} \ = \ \left[Cr^{+2}\right]^3\left[PO_4^{-3}\right]^2 \ = \ \left(3.42\times10^{-7}\right)^3\left(2.28\times10^{-7}\ M\right)^2 \ = \ 2.08\times10^{-33}$$