5.4 – Special K's – Equilibrium Solubility - Assignment

1. Write the balanced equation and the solubility product constant expression, K_{sp}, for the each of the following dissociation reactions. All compounds are solids. One has been given as an example.

Reminders
- ion charges MUST BE included.
- solids (and liquids) are NOT included in the equilibrium expression
- don't forget to include exponents when needed
- polyatomic ions (e.g. CO_3^-) do not break apart

Compound	Equation	K_{sp}
$(NH_4)_2S$	$(NH_4)_2O\ (s) \rightleftharpoons 2\ NH_4^+(aq) + S^{2-}(aq)$	$K_{sp} = [NH_4^+]^2[S^{2-}]$
CaS	$CaS_{(s)} \rightleftharpoons Ca^{2+}_{(aq)} + S^{2-}_{(aq)}$	$Ksp = [Ca^{2+}][S^{2-}]$
K_2SO_4	$K_2SO_{4(s)} \rightleftharpoons 2K^+_{(aq)} + SO_4^{2-}{}_{(aq)}$	$Ksp = [K^+]^2[SO_4^{2-}]$
$Mg(OH)_2$	$Mg(OH)_{2(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$	$Ksp = [Mg^{2+}][OH^-]^2$

2. Organize the following salts in order of solubility (highest to lowest):

AgCl; $K_{sp} = 1.8 \times 10^{-10}$ AgI; $K_{sp} = 8.5 \times 10^{-17}$ AgBr; $K_{sp} = 5.4 \times 10^{-13}$

AgCl, AgBr, AgI

3. Calculate K_{sp} for a saturated nickel(II) sulfide, NiS, solution with a solubility of 3.27×10^{-11}. Calculate the K_{sp}.

$$NiS_{(s)} \rightleftharpoons Ni^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

3.27×10^{-11} M $\longrightarrow$

$$Ksp = [Ni^{2+}][S^{2-}] = (3.27\times10^{-11}M)(3.27\times10^{-11}M)$$

$$Ksp = 1.07\times10^{-21}$$

4. Calculate the concentration of ions in a saturated solution of $CaCO_3$ in water at 25°C. K_{sp} for $CaCO_3$ is 4.8×10^{-9}.

$$CaCO_3 \rightleftharpoons Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

$$[Ca^{2+}] = [CO_3^{2-}] = x$$

$$\underset{Ksp}{4.8\times10^{-9}} = [Ca^{2+}][CO_3^{2-}]$$

$$\sqrt{4.8\times10^{-9}} = \sqrt{x^2}$$

$$\boxed{x = 6.93\times10^{-5}M}$$

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5. Calculate the concentrations of ions at 25°C for a saturated solution of silver bromate (Ksp = 5.3 x 10^{-5}).

$AgBrO_3 \rightleftharpoons Ag^+_{(aq)} + BrO_3^-{}_{(aq)}$ let $x = [Ag^+] = [BrO_3^-]$

$K_{sp} = [Ag^+][BrO_3^-] = (x)(x)$

$5.3 \times 10^{-5} = x^2$

$x = 0.0073M$ $\therefore [Ag^+] = [BrO_3^-] = 0.0073M$.

6. At 25°C, 0.0024 g of $Ce(OH)_3$ is contained in a 2.5 L solution. Calculate K_{sp}.

$C = \frac{wt}{mm \cdot V} = \frac{0.0024g}{(191.15\frac{g}{mol})(2.5L)} = 5.0 \times 10^{-6}M$

$Ce(OH)_{3(s)} \rightleftharpoons Ce^{3+}_{(aq)} + 3OH^-_{(aq)}$ $[Ce^{3+}] = 5.0 \times 10^{-6}M$

$[OH^-] = 3(5.0 \times 10^{-6}M)$
$= 1.5 \times 10^{-5}M$

$K_{sp} = [Ce^{3+}][OH^-]^3 = (5.0 \times 10^{-6})(1.5 \times 10^{-5})^3$

$\boxed{K_{sp} = 1.7 \times 10^{-20}}$

7. What is the mass of calcium fluoride present in a saturated 1.5 L solution?

$K_{sp} = 3.9 \times 10^{-11}$

$CaF_2 \rightleftharpoons Ca^{2+}_{(aq)} + 2F^-_{(aq)}$ let $x = [Ca^{2+}]$ $\therefore 2x = [F^-]$

$K_{sp} = [Ca^{2+}][F^-]^2 = (x)(2x)^2$

$3.9 \times 10^{-11} = 4x^3$

$9.75 \times 10^{-12} = x^3$

$x = 2.1 \times 10^{-4}M = [Ca^{2+}] = [CaF_2]$

$wt = C \cdot mm \cdot V$
$= (2.1 \times 10^{-4})(78.076\frac{g}{mol})(1.5L)$
$\boxed{= 0.025g}$

Final Volume = 900mL

8. 400.0 mL of 4.00 x 10^{-10} M $Al(NO_3)_3$ is mixed with 500.0 mL of 3.00 x 10^{-7} M NaOH. If K_{sp} for $Al(OH)_3$ is 5.00 x 10^{-33} at this temperature, will there be a precipitate?

$Al(OH)_3 \rightleftharpoons Al^{3+}_{(aq)} + 3OH^-_{(aq)}$

$Al(NO_3)_3 \rightarrow M_1V_1 = M_2V_2$

$(4.0 \times 10^{-10})(0.4) = M_2(0.9)$

$M_2 = 1.78 \times 10^{-10}M = [Al^{3+}]$

$NaOH \rightarrow M_1V_1 = M_2V_2$

$(3.0 \times 10^{-7})(0.5) = M_2(0.9)$

$M_2 = 1.67 \times 10^{-7}M = [OH^-]$

$Q = [Al^{3+}][OH^-]^3 = (1.78 \times 10^{-10})(1.67 \times 10^{-7})^3 = 8.29 \times 10^{-31}$

$Q > K_{sp}$ $\therefore$ yes.

$Ksp = 2.0 \times 10^{-4}$

9. Will a precipitate form if 20.0 mL of 0.0100 M $CaCl_2$ are mixed with 20.0 mL of 0.00800 M Na_2SO_4 at 25.0 °C?

$CaCl_2 + Na_2SO_4 \rightarrow NaCl_{(aq)} + CaSO_{4(s)}$

$CaSO_{4(s)} \rightleftharpoons Ca^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$

$CaCl_2 : M_1V_1 = M_2V_2$

$(0.01M)(0.02L) = M_2(0.04L)$

$M_2 = 0.005M = [Ca^{2+}]$

$Na_2SO_4 : (0.008M)(0.02L) = M_2(0.04L)$

$M_2 = 0.004M = [SO_4^{2-}]$

$Q = [Ca^{2+}][SO_4^{2-}] = (0.005M)(0.004M)$

$Q = 2.00 \times 10^{-5}$

$\boxed{Q < Ksp \therefore NO}$

10. Will a precipitate form if 40.0 mL of 8.0×10^{-3} M $Mg(NO_3)_2$ are mixed with 60.0 mL of 1.00×10^{-2} M K_2CO_3? (K_{sp} for $MgCO_3 = 2.60 \times 10^{-5}$)

removed

removed

~~$Q < Ksp \therefore NO$~~

~~$Q = 2.00 \times 10^{-5}$~~

$Ksp = 1.1 \times 10^{-12}$

11. Will a precipitate form if 25 mL of 4.0×10^{-3} M $AgNO_3$ are mixed with 75 mL of 2.0×10^{-4} M Na_2CrO_4 at 25.0 °C?

$AgNO_3 + Na_2CrO_4 \rightarrow NaNO_3 + Ag_2CrO_4$

$Ag_2CrO_{4(s)} \rightleftharpoons 2Ag^+_{(aq)} + CrO_4^{2-}_{(aq)}$

$M_1V_1 = M_2V_2$

$AgNO_3 : (4.0 \times 10^{-3})(0.025L) = M_2(0.1L)$

$M_2 = 0.001M = [Ag^+]$

$Na_2CrO_4 : (2.0 \times 10^{-4})(0.075L) = M_2(0.1L)$

$M_2 = 1.5 \times 10^{-4}M = [CrO_4^{2-}]$

$Q = [Ag^+]^2[CrO_4^{2-}] = (0.001)^2(1.5 \times 10^{-4}M)$

$= 1.5 \times 10^{-10}$

$\boxed{Q > Ksp \therefore yes}$

12. What is the maximum $[Sr^{2+}]$ that can be dissolved in a 0.020 M solution of K_2SO_4 without precipitating $SrSO_4$? (K_{sp} of $SrSO_4 = 7.6 \times 10^{-7}$)

$SrSO_{4(s)} \rightleftharpoons Sr^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$

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

$7.6 \times 10^{-7} = x\,(0.020M)$

$\boxed{x = 3.8 \times 10^{-5}M}$