Wkst 3.2: K_{sp} Calculations

1- Calculate the solubility product constant or solubility of the following:

a) $Pb_3(AsO_4)_2$, whose solubility is 3.26×10^{-8} M

b) Hg_2CrO_4, whose solubility is 7.9×10^{-4} M

c) $Mg(OH)_2$ whose K_{sp} is 1.1×10^{-8}

d) $La(IO_3)_3$ whose K_{sp} is 6.1×10^{-12}

2- The K_{sp} of scandium (III) hydroxide is 4.2×10^{-18}. Find its solubility in $g \bullet L^{-1}$.

3- The solubility of $PbSO_4$ in water is 3.8×10^{-2} $g \bullet L^{-1}$. Calculate the K_{sp} of $PbSO_4$.

4- $[Ag^+] = 2.2 \times 10^{-4}$ M in a saturated solution of $Ag_2C_2O_4$. Determine the solubility product of the compound.

5- SrF_2 has a $K_{sp} = 2.18 \times 10^{-8}$. Determine the concentrations of the strontium and fluoride ions in a saturated solution.

6- $[IO_3^-] = 3.58 \times 10^{-3}$ M in a saturated solution of $Cd(IO_3)_2$. Determine the solubility product of the compound.

7- Li_3PO_4 has a $K_{sp} = 3.2 \times 10^{-9}$. Find its solubility in $g \bullet L^{-1}$.

8- How many grams of thallium (I) sulphide can you dissolve in 500. mL of solution to achieve saturation? $K_{sp} = 6.00 \times 10^{-22}$.

9- How many grams of PbI_2 will dissolve in 250. mL of water to form a saturated solution if its solubility product equals 1.7×10^{-5}?

10- What is the volume of saturated solution of $PbSO_4$ which can be prepared from 1.5 g of the compound?

11- A student reduces the volume of a saturated solution of lead (II) bromide from 10.0 L to 7.50 L by evaporation. What is the mass of precipitated lead (II) bromide?

12- Determine the maximum volume of saturated solution obtained by dissolving 7.50 grams of iron (II) hydroxide in water.

13- A student adds 0.500 grams of strontium fluoride to 2.00 L of water. He obtains a suspension of strontium fluoride. Determine the minimum volume of water that needs to be added to dissolve all the strontium fluoride.

1. a) $Pb_3(AsO_4)_{2(s)} \rightleftharpoons 3Pb^{2+}_{(aq)} + 2AsO_4^{3-}_{(aq)}$

S → 3S, 2S

$K_{sp} = (3s)^3(2s)^2$

$= 108s^5$

$= 108(3.26 \cdot 10^{-8})^5$

$= \boxed{3.98 \cdot 10^{-36}}$

$s = 3.26 \cdot 10^{-8}$

b) $Hg_2CrO_{4(s)} \rightleftharpoons 2Hg^{+}_{(aq)} + CrO_4^{2-}_{(aq)}$

S → 2S, S

$K_{sp} = (2s)^2(s)$

$= 4s^3$

$= 4(7.9 \cdot 10^{-4})^3$

$= \boxed{2.0 \cdot 10^{-9}}$

$s = 7.9 \cdot 10^{-4}$

c) $Mg(OH)_{2(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2OH^{-}_{(aq)}$

S → S, 2S

$K_{sp} = (s)(2s)^2$

$= 4s^3$

$1.1 \cdot 10^{-8} = 4s^3$

$s = \sqrt[3]{\frac{1.1 \cdot 10^{-8}}{4}}$

$= \boxed{1.4 \cdot 10^{-3} M}$

$K_{sp} = 1.1 \cdot 10^{-8}$

d) $La(IO_3)_{3(s)} \rightleftharpoons La^{3+}_{(aq)} + 3IO_3^{-}_{(aq)}$

S → S, 3S

$K_{sp} = (s)(3s)^3$

$= 27s^4$

$6.1 \cdot 10^{-12} = 27s^4$

$s = \sqrt[4]{\frac{6.1 \cdot 10^{-12}}{27}}$

$= \boxed{6.9 \cdot 10^{-4} M}$

$K_{sp} = 6.1 \cdot 10^{-12}$

2. $Sc(OH)_{3(s)} \rightleftharpoons Sc^{3+}_{(aq)} + 3OH^{-}_{(aq)}$

S → S, 3S

$K_{sp} = (s)(3s)^3$

$= 27s^4$

$4.2 \cdot 10^{-18} = 27s^4$

$s = \sqrt[4]{\frac{4.2 \cdot 10^{-18}}{27}}$

$= 2.0 \cdot 10^{-5} M$

$K_{sp} = 4.2 \cdot 10^{-18}$

$\frac{2.0 \cdot 10^{-5} \text{ mol}}{L} \times \frac{96.0 \text{ g}}{1 \text{ mol } Sc(OH)_3} = \boxed{1.9 \cdot 10^{-3} \text{ g/L}}$

3. $PbSO_{4(s)} \rightleftharpoons Pb^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$

S S

$\frac{3.8 \cdot 10^{-2}\ g}{L} \times \frac{1\ mol\ PbSO_4}{303.3\ g} = 1.3 \cdot 10^{-4} M = S$

$K_{sp} = s^2$

$= (1.3 \cdot 10^{-4})^2$

$= \boxed{1.7 \cdot 10^{-8}}$

4. $Ag_2C_2O_{4(s)} \rightleftharpoons 2Ag^+_{(aq)} + C_2O_4^{2-}_{(aq)}$

S 2S S

$2.2 \cdot 10^{-4} M$ $1.1 \cdot 10^{-4} M$

$\div 2$

$K_{sp} = [Ag^+]^2[C_2O_4^{2-}]$

$= (2.2 \cdot 10^{-4})^2 (1.1 \cdot 10^{-4})$

$= \boxed{5.3 \cdot 10^{-12}}$

5. $SrF_{2(s)} \rightleftharpoons Sr^{2+}_{(aq)} + 2F^-_{(aq)}$

S s 2s

$K_{sp} = 2.18 \cdot 10^{-8}$

$K_{sp} = (s)(2s)^2$

$2.18 \cdot 10^{-8} = 4s^3$

$s = \sqrt[3]{\frac{2.18 \cdot 10^{-8}}{4}}$

$= 1.76 \cdot 10^{-3}$

$\boxed{[Sr^{2+}] = 1.76 \cdot 10^{-3} M}$

$\boxed{[F^-] = 3.52 \cdot 10^{-3} M}$

6. $Cd(IO_3)_{2(s)} \rightleftharpoons Cd^{2+}_{(aq)} + 2IO_3^-_{(aq)}$

S s 2s

$1.79 \cdot 10^{-3} M$ $3.58 \cdot 10^{-3} M$

$\div 2$

$K_{sp} = (s)(2s)^2$

$= (1.79 \cdot 10^{-3})(3.58 \cdot 10^{-3})^2$

$= \boxed{2.29 \cdot 10^{-8}}$

7. $Li_3PO_{4(s)} \rightleftharpoons 3Li^+_{(aq)} + PO_4^{3-}_{(aq)}$

S 3s S

$K_{sp} = 3.2 \cdot 10^{-9}$

$K_{sp} = (3s)^3(s)$

$3.2 \cdot 10^{-9} = 27s^4$

$s = \sqrt[4]{\frac{3.2 \cdot 10^{-9}}{27}}$

$= 3.3 \cdot 10^{-3} M$

$\frac{3.3 \cdot 10^{-3}\ mol}{L} \times \frac{115.7\ g}{1\ mol\ Li_3PO_4} = \boxed{3.8 \cdot 10^{-1}\ g/L}$

8. $Tl_2S_{(s)} \rightleftharpoons 2Tl^+_{(aq)} + S^{2-}_{(aq)}$

S 2S S

$K_{sp} = 6.00 \cdot 10^{-22}$

$K_{sp} = 4s^3$

$6.00 \cdot 10^{-22} = 4s^3$

$s = \sqrt[3]{\frac{6.00 \cdot 10^{-22}}{4}}$

$= 5.31 \cdot 10^{-8} M$

$500.\,mL \times \frac{1\,L}{1000\,mL} \times \frac{5.31 \cdot 10^{-8}\,mol}{1\,L} \times \frac{440.9\,g}{1\,mol\,Tl_2S} = \boxed{1.17 \cdot 10^{-5}\,g}$

9. $PbI_{2\,(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2I^-_{(aq)}$

S S 2S

$K_{sp} = 1.7 \cdot 10^{-5}$

$K_{sp} = (s)(2s)^2$

$1.7 \cdot 10^{-5} = 4s^3$

$s = \sqrt[3]{\frac{1.7 \cdot 10^{-5}}{4}}$

$= 1.6 \cdot 10^{-2} M$

$250\,mL \times \frac{1\,L}{1000\,mL} \times \frac{1.6 \cdot 10^{-2}\,mol}{1\,L} \times \frac{461.0\,g}{1\,mol\,PbI_2} = \boxed{1.8\,g}$

10. $PbSO_{4\,(s)} \rightleftharpoons Pb^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$

S S S

$K_{sp} = 1.8 \cdot 10^{-8}$ (from table)

$K_{sp} = s^2$

$1.8 \cdot 10^{-8} = s^2$

$s = 1.3 \cdot 10^{-4} M$

$1.5\,g\,PbSO_4 \times \frac{1\,mol}{303.3\,g} \times \frac{1\,L}{1.3 \cdot 10^{-4}\,mol} = \boxed{38\,L}$

11. $PbBr_{2\,(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Br^-_{(aq)}$

S S 2S

* At 10.0L, the solution is saturated. If the volume is reduced to 7.50L, the mass of the precipitate will be found in the 2.50L that evaporated.

$K_{sp} = 6.6 \cdot 10^{-6} = 4s^3$

$s = \sqrt[3]{\frac{6.6 \cdot 10^{-6}}{4}}$

$= 1.2 \cdot 10^{-2} M$

$2.50\,L \times \frac{1.2 \cdot 10^{-2}\,mol}{1\,L} \times \frac{367.0\,g}{1\,mol\,PbBr_2} = \boxed{11\,g}$

12. $Fe(OH)_{2\,(s)} \rightleftharpoons Fe^{2+}_{(aq)} + 2OH^-_{(aq)}$

$\quad\quad\quad\quad\quad\quad\quad\quad\quad s \quad\quad\quad 2s$

$K_{sp} = 4.9 \cdot 10^{-17} = 4s^3$

$s = \sqrt[3]{\frac{4.9 \cdot 10^{-17}}{4}}$

$= 2.3 \cdot 10^{-6} M$

$7.50\,g \times \frac{1\,mol\ Fe(OH)_2}{89.8\,g} \times \frac{1\,L}{2.3 \cdot 10^{-6}\,mol} = \boxed{3.6 \cdot 10^4\,L}$

13. $SrF_{2\,(s)} \rightleftharpoons Sr^{2+}_{(aq)} + 2F^-_{(aq)}$

$s \quad\quad\quad\quad s \quad\quad\quad 2s$

$K_{sp} = 4.3 \cdot 10^{-9} = 4s^3$

$s = \sqrt[3]{\frac{4.3 \cdot 10^{-9}}{4}}$

$= 1.0 \cdot 10^{-3} M$

$0.500\,g \times \frac{1\,mol}{125.6\,g} \times \frac{1\,L}{1.0 \cdot 10^{-3}\,mol} = 4.0\,L$

To dissolve all of the 0.500g of SrF_2, 4.0L is needed.
The extra volume of water needed is :

$4.0\,L - 2.00\,L = \boxed{2.0\,L}$