XI) Type D Problems: Determining the Concentration of a Specific Ion in a Saturated Solution

Recall that there are two ways to make a saturated solution: the direct method and the indirect method. Explain each using $Pb(OH)_2$ as an example.

1. Direct Method: add $Pb(OH)_2$ salt to water + stir.... Keep adding until there is excess $Pb(OH)_2$ solid at the bottom.

2. Indirect Method: mix two (aq) solutions: one that contains Pb^{2+} and the other OH^-, in concentrations that exceed the solubility of $Pb(OH)_2$.

It is important to recognize that ion stoichiometry for a saturated solution is only a reality when the saturated solution is made from dissolving the salt in water directly. Direct.
What would be the proportion of $[OH^-]$ compared to $[Pb^{2+}]$ in this case?

$Pb(OH)_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2OH^-_{(aq)}$ $1\,Pb^{2+} : 2\,OH^-$

If a saturated solution of a salt is made by combining two different solutions (indirectly), the $[Pb^{2+}]$ relative to the $[OH^-]$ could be anything, depending on the molarities of the solutions mixed. Therefore, you can't rely on 2 OH^- to 1 Pb^{2+} stoichiometry because the ions came from different solutions. However, the K_{sp} can still be relied upon, as you'll see in Type D problems.

Example:

1. What is the maximum $[Sr^{2+}]$ that can be dissolved in a 0.020M solution of K_2SO_4 without a precipitate of $SrSO_4$ forming?

$1\,K_2SO_{4(aq)} \rightarrow 2K^+_{(aq)} + 1SO_4^{2-}{}_{(aq)}$
0.020M → 0.040M (×2), 0.020M

(from table) $K_{sp} = [Sr^{2+}][SO_4^{2-}]$
$3.4\times10^{-7} = ?\,(0.020M)$

$SrSO_{4(s)} \rightleftharpoons Sr^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$
solve for $[Sr^{2+}]$ → ? 0.020M
use Ksp for $SrSO_4$.

$[Sr^{2+}] = \frac{3.4\times10^{-7}}{0.020M}$

$[Sr^{2+}] = 1.7\times10^{-5}\,M$

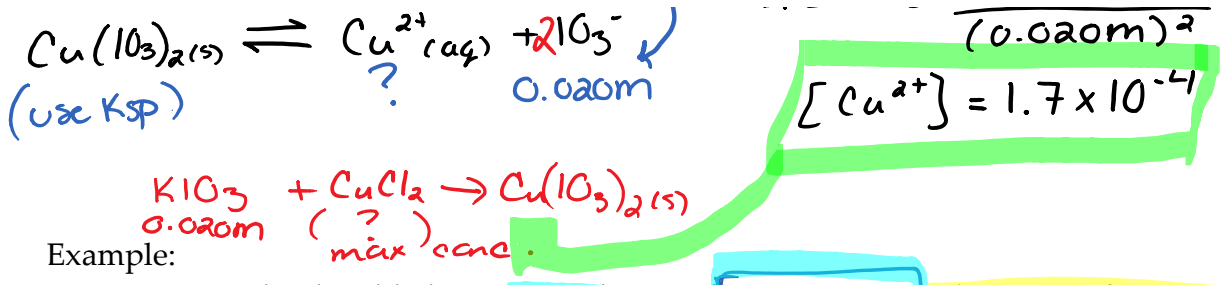
any $[Sr^{2+}]$ ↑ would result in a ppt.

2. If Cu^{2+} is slowly added to a solution of 0.020M KIO_3, at what $[Cu^{2+}]$ does a precipitate of $Cu(IO_3)_2$ just start to form?

$KIO_{3(aq)} \rightarrow K^+_{(aq)} + IO_3^-{}_{(aq)}$
0.020M → 0.020M

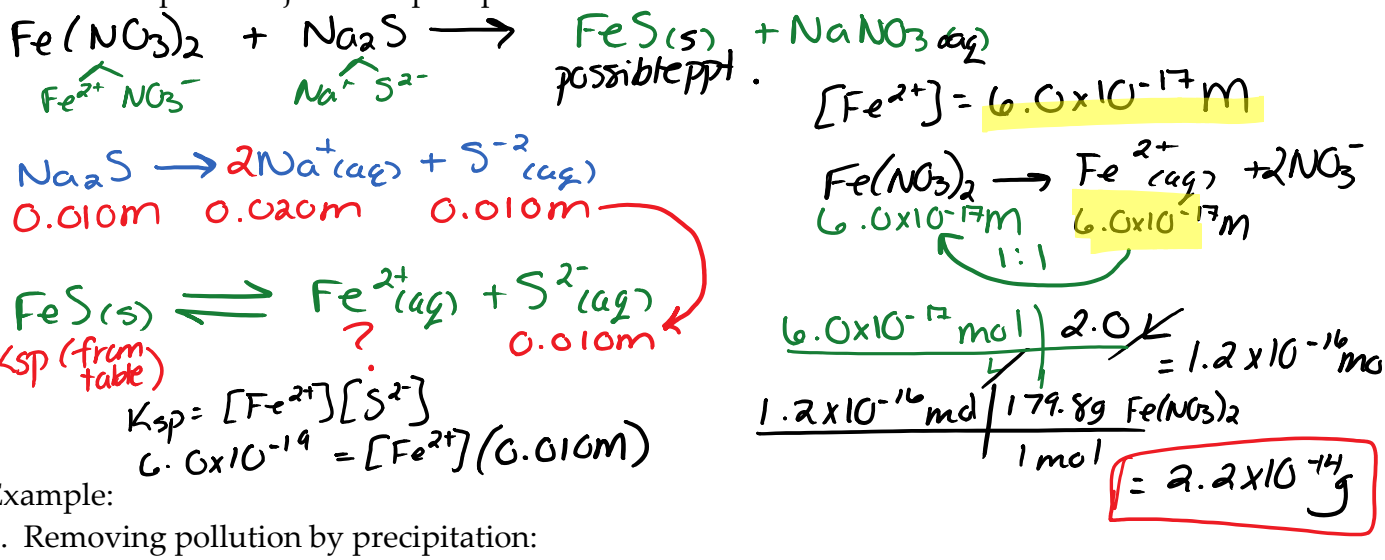
$Cu(IO_3)_{2(s)} \rightleftharpoons Cu^{2+}_{(aq)} + 2IO_3^-$
? 0.020M

$K_{sp} = [Cu^{2+}][IO_3^-]^2$
$6.9\times10^{-8} = [Cu^{2+}](0.020M)^2$
$\therefore [Cu^{2+}] = \frac{6.9\times10^{-8}}{(0.020M)^2}$
$[Cu^{2+}] = 1.7\times10^{-4}$



Example:

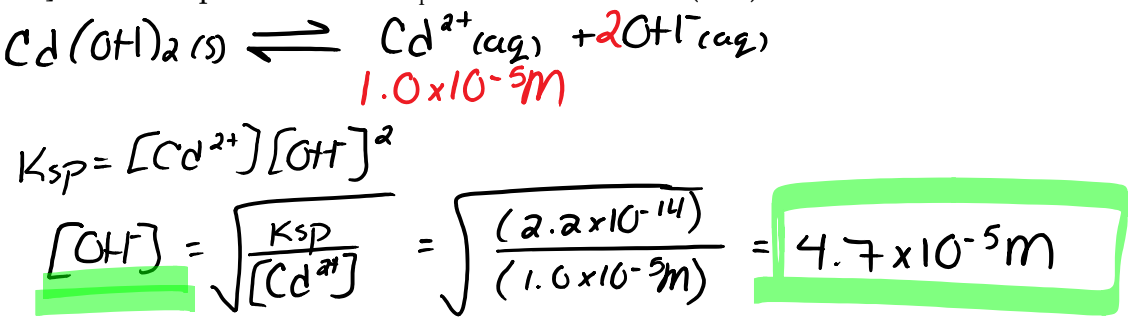
3. $Fe(NO_3)_2$ is slowly added to a 2.0L solution of 0.010M Na_2S. What mass of $Fe(NO_3)_2$ would be required to just start precipitation?



Example:

4. Removing pollution by precipitation:

Waste water from a mining operation was found to have a $[Cd^{2+}]$ exceeding environmental standards. Before discharging the water into an adjacent river, the $[Cd^{2+}]$ in the tank must be lowered to 1.0×10^{-5}M. What $[OH^-]$ would be required to bring the $[Cd^{2+}]$ to an acceptable level? $K_{sp} = 2.2 \times 10^{-14}$ for $Cd(OH)_2$



Assignment 9: Type D Exercises

1. What $[S^{2-}]$ must be present to just start precipitation from a 0.20M solution of $CuCl_2$?
2. What $[Cu^{2+}]$ would be required to just start precipitation of $Cu(IO_3)_2$ from a 0.20M solution of KIO_3?

3. $AgNO_3$ is added to a 0.10M solution of NaCl. What $[Ag^+]$ must be present in order to observe a precipitate?
4. What is the maximum $[SO_4^{2-}]$ that can be present in 0.010M $CaBr_2$ solution without a precipitate forming?
5. What $[Ba^{2+}]$ must be present to just start a precipitation in a 5.0×10^{-4}M solution of K_2CrO_4?