

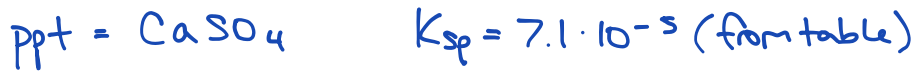
Worksheet 3.3: More K_{sp} Problems

1. A solution has a concentration of calcium ions equal to 2.5×10^{-2} M. What is the maximum concentration of sulphate ions allowed without causing precipitation?
2. A solution has a concentration of chromate ions equal to 3.00×10^{-4} M. What is the maximum concentration of silver nitrate allowed without causing precipitation?
3. A student needs to determine the concentration of carbonate ion in a sample of well water. She uses a 10.0 L sample of well water and finds she needed to add 1.75 g of calcium chloride before a precipitate of calcium carbonate appeared. What is the concentration of carbonate ion in the sample?
4. Up to 15.0 g of barium chloride can be dissolved in 2.5 L of $Al_2(SO_4)_3$ solution without occurrence of a precipitate. Find the concentration of the aluminum sulphate solution.
5. A saturated solution of silver bromate is prepared by adding 5.00 g of silver nitrate to a 2.5×10^{-2} M solution of $NaBrO_3$. What is the maximum volume of solution produced?
6. What is the maximum mass of copper (II) chloride you can add to a 100.0 L of a 0.025 M solution of sodium iodate without causing precipitation?
7. What is the maximum volume of 0.0350 M sodium sulphate solution required to obtain a saturated solution of strontium sulphate with 1.25 g of strontium nitrate?
8. 2.50 g of sodium chromate and 1.25 g of barium chloride are added to 50.0 L of water. Is the barium chromate solution obtained saturated?
9. Will a precipitate form if 750. mL of 2.0×10^{-2} M $MgCl_2$ is mixed with 2.50 L of 0.010 M Cs_2CO_3 ?
10. Will a precipitate form if 250. mL of 2.5×10^{-3} M $Sr(NO_3)_2$ is mixed with 2500. mL of 3.00×10^{-4} M $Na_2C_2O_4$? K_{sp} of $SrC_2O_4 = 4.00 \times 10^{-7}$.
11. Will a precipitate form if 250. mL of 0.500 M $Pb(NO_3)_2$ is mixed with 750. mL of 0.0250M $CaCl_2$?
12. Will a precipitate form if 500. mL of 1.20×10^{-2} M $SrCl_2$ is mixed with 500. mL of 8.00×10^{-3} M $Al_2(SO_4)_3$?

Day 1

1. $[Ca^{2+}] = 2.5 \cdot 10^{-2} M$

$[SO_4^{2-}] = ?$



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

$$7.1 \cdot 10^{-5} = (2.5 \cdot 10^{-2})[SO_4^{2-}]$$

$$\boxed{[SO_4^{2-}] = 2.8 \cdot 10^{-3} M}$$

2. $[CrO_4^{2-}] = 3.00 \cdot 10^{-4} M$

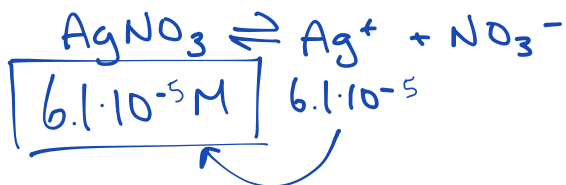
$[AgNO_3] = ?$



$$K_{sp} = [Ag^+]^2 [CrO_4^{2-}]$$

$$1.1 \cdot 10^{-12} = [Ag^+]^2 (3.00 \cdot 10^{-4})$$

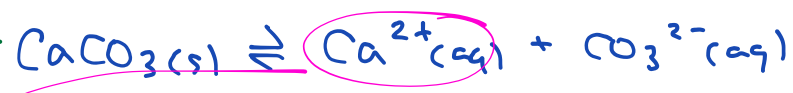
$$[Ag^+] = \sqrt{\frac{1.1 \cdot 10^{-12}}{3.00 \cdot 10^{-4}}} = 6.1 \cdot 10^{-5}$$



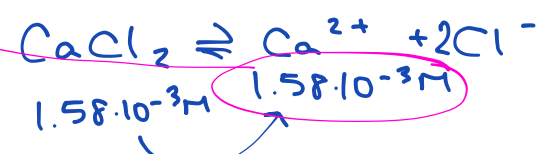
3. $[CO_3^{2-}] = ?$

$CaCl_2 = 1.75g$ in $10.0L$

ppt = $CaCO_3$ $K_{sp} = 5.0 \cdot 10^{-9}$ (from table)

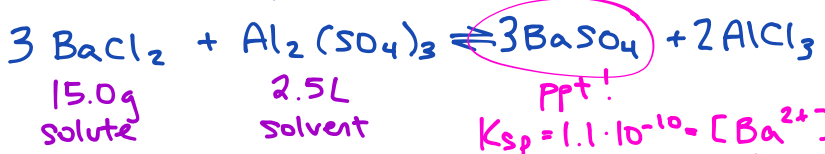


$1.75g CaCl_2 \times \frac{1 \text{ mol}}{111.1g} \times \frac{1}{10.0L} = 1.58 \cdot 10^{-3}M$



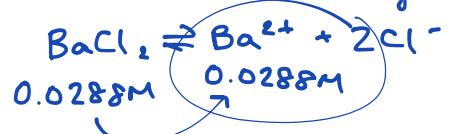
$K_{sp} = [Ca^{2+}][CO_3^{2-}]$
 $5.0 \cdot 10^{-9} = (1.58 \cdot 10^{-3})[CO_3^{2-}]$
 $[CO_3^{2-}] = 3.2 \cdot 10^{-6}M$

4. $BaCl_2 = 15.0g \rightarrow Al_2(SO_4)_3 = 2.5L$
 $[Al_2(SO_4)_3] = ?$



$K_{sp} = 1.1 \cdot 10^{-10} = [Ba^{2+}][SO_4^{2-}]$
 comes from $BaCl_2$

$[BaCl_2] = \frac{15.0g}{1} \times \frac{1 \text{ mol}}{208.3g} \times \frac{1}{2.5L} = 0.0288M$



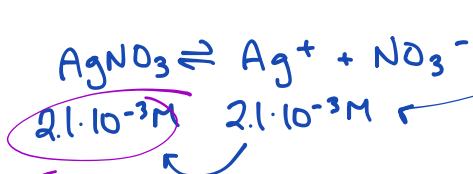
$K_{sp} = 1.1 \cdot 10^{-10} = (0.0288)[SO_4^{2-}]$
 $[SO_4^{2-}] = 3.8 \cdot 10^{-9}M$

$Al_2(SO_4)_3 \rightleftharpoons 2Al^{3+} + 3SO_4^{2-}$
 $1.3 \cdot 10^{-9}M$ $\div 3$ $3.8 \cdot 10^{-9}M$

5. $\text{AgNO}_3 = 5.00 \text{ g} \Rightarrow [\text{NaBrO}_3] = 2.5 \cdot 10^{-2} \text{ M}$
 volume of $\text{AgNO}_3 = ?$ 1:1 ratio

ppt = $\text{AgBrO}_3 / K_{sp} = 5.3 \cdot 10^{-5} = [\text{Ag}^+][\text{BrO}_3^-]$
 $2.5 \cdot 10^{-2} \text{ M}$

$[\text{Ag}^+] = 2.1 \cdot 10^{-3} \text{ M}$



$5.00 \text{ g } \text{AgNO}_3 \times \frac{1 \text{ mol}}{169.9 \text{ g}} \times \frac{1 \text{ L}}{2.1 \cdot 10^{-3} \text{ mol}} = 14 \text{ L}$

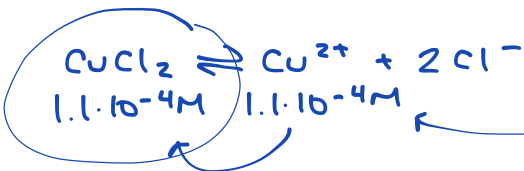
(5.00 g of AgNO_3 must be dissolved in 14 L of solution to get a [] of $2.1 \cdot 10^{-3} \text{ M}$)

6. CuCl_2 mass = ? 100.0 L
 $[\text{NaIO}_3] = 0.025 \text{ M}$



$K_{sp} = [\text{Cu}^{2+}][\text{IO}_3^-]^2 = 6.9 \cdot 10^{-8}$

$[\text{Cu}^{2+}] = \frac{6.9 \cdot 10^{-8}}{(0.025)^2} = 1.1 \cdot 10^{-4} \text{ M}$



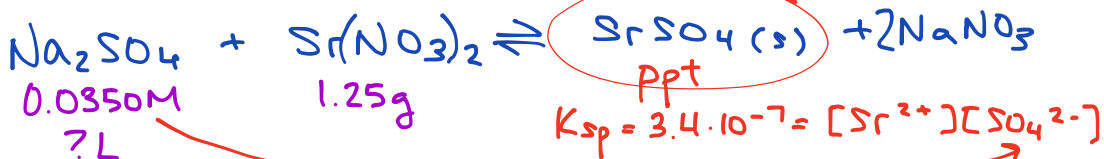
? g $\text{CuCl}_2 = \frac{1.1 \cdot 10^{-4} \text{ mol}}{1} \times \frac{100.0 \text{ L}}{1} \times \frac{134.2 \text{ g}}{1 \text{ mol}} = 1.5 \text{ g}$

$$7. [\text{Na}_2\text{SO}_4] = 0.0350\text{M}$$

$$= ? \text{ L}$$

SrSO_4 ppt

$$\text{Sr}(\text{NO}_3)_2 = 1.25\text{g}$$



$$0.0350\text{M}$$

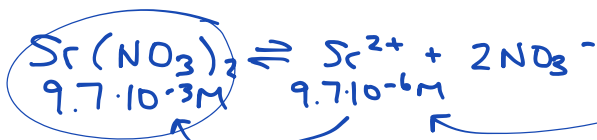
$$? \text{ L}$$

$$1.25\text{g}$$

1:1 ratio

$$[\text{Sr}^{2+}] = \frac{3.4 \cdot 10^{-7}}{0.0350\text{M}}$$

$$= 9.7 \cdot 10^{-6}\text{M}$$



$$1.25\text{g } \text{Sr}(\text{NO}_3)_2 \times \frac{1\text{mol}}{211.6\text{g}} \times \frac{1\text{L}}{9.7 \cdot 10^{-6}\text{mol}} = \boxed{609\text{L}}$$

Day 1

$$8. 2.50\text{g } \text{Na}_2\text{CrO}_4$$

$$[\text{Na}_2\text{CrO}_4] = [\text{CrO}_4^{2-}] = \frac{2.50\text{g}}{1} \times \frac{1\text{mol}}{162\text{g}} \times \frac{1}{50.0\text{L}} = 3.09 \cdot 10^{-4}\text{M}$$

(1:1 ratio)

$$1.25\text{g } \text{BaCl}_2$$

$$[\text{BaCl}_2] = [\text{Ba}^{2+}] = \frac{1.25\text{g}}{1} \times \frac{1\text{mol}}{208.3\text{g}} \times \frac{1}{50.0\text{L}} = 1.20 \cdot 10^{-4}\text{M}$$

(1:1 ratio)

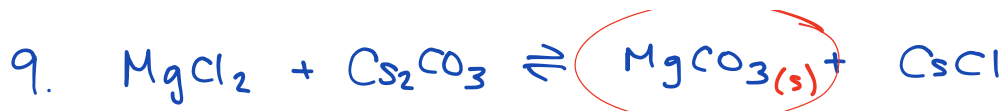
$$\text{TIP} = [\text{Ba}^{2+}][\text{CrO}_4^{2-}] = (1.20 \cdot 10^{-4})(3.09 \cdot 10^{-4})$$

$$= 3.71 \cdot 10^{-8}$$

$$\text{Actual } K_{sp} = 1.2 \cdot 10^{-10} \quad \leftarrow$$

Trial > Actual

∴ Solution is saturated
(past saturation & ppt will form)



$$4.6 \cdot 10^{-3} \text{M} \quad \rightarrow \quad 4.6 \cdot 10^{-3} \text{M}$$

$$C_1 V_1 = C_2 V_2$$

$$(2.0 \cdot 10^{-2})(750.0) = C_2 (3250)$$

$$C_2 = 4.6 \cdot 10^{-3} \text{M}$$

$$\text{TIP} = [\text{Mg}^{2+}][\text{CO}_3^{2-}]$$

$$= (4.6 \cdot 10^{-3})(7.7 \cdot 10^{-3})$$

$$= 3.5 \cdot 10^{-5}$$



$$7.7 \cdot 10^{-3} \text{M} \quad \rightarrow \quad 7.7 \cdot 10^{-3} \text{M}$$

$$C_1 V_1 = C_2 V_2$$

$$(0.010)(2500) = C_2 (3250)$$

$$C_2 = 7.7 \cdot 10^{-3} \text{M}$$

$$\text{Actual } K_{sp} = 6.8 \cdot 10^{-6}$$

TIP > Actual
 \therefore ppt will form



$$2.3 \cdot 10^{-4} \text{M} \quad \rightarrow \quad 2.3 \cdot 10^{-4} \text{M}$$

$$C_1 V_1 = C_2 V_2$$

$$(2.5 \cdot 10^{-3})(250) = C_2 (2750)$$

$$C_2 = 2.3 \cdot 10^{-4} \text{M}$$

$$\text{TIP} = [\text{Sr}^{2+}][\text{C}_2\text{O}_4^{2-}]$$

$$= (2.3 \cdot 10^{-4})(2.7 \cdot 10^{-4})$$

$$= 6.2 \cdot 10^{-8}$$



$$2.7 \cdot 10^{-4} \text{M} \quad \rightarrow \quad 2.7 \cdot 10^{-4} \text{M}$$

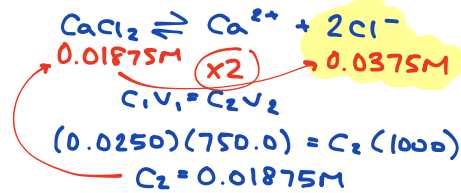
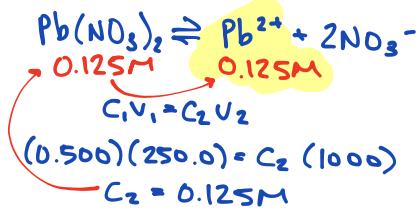
$$C_1 V_1 = C_2 V_2$$

$$(3.00 \cdot 10^{-4})(2500) = C_2 (2750)$$

$$C_2 = 2.7 \cdot 10^{-4} \text{M}$$

$$\text{Actual } K_{sp} = 4.00 \cdot 10^{-7}$$

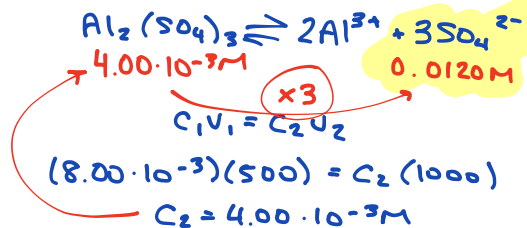
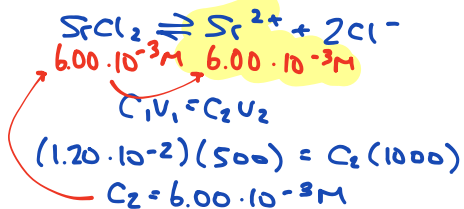
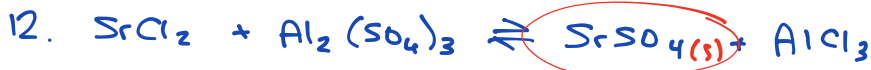
TIP < Actual
 \therefore ppt will not form



$$\begin{aligned} \text{TIP} &= [\text{Pb}^{2+}][\text{Cl}^-]^2 \\ &= (0.125)(0.0375)^2 \\ &= 1.76 \cdot 10^{-4} \end{aligned}$$

$$\text{Actual } K_{sp} = 1.2 \cdot 10^{-5}$$

TIP > Actual
 \therefore ppt will form



$$\begin{aligned} \text{TIP} &= [\text{Sr}^{2+}][\text{SO}_4^{2-}] \\ &= (6.00 \cdot 10^{-3})(0.0120) \\ &= 7.20 \cdot 10^{-5} \end{aligned}$$

$$\text{Actual } K_{sp} = 3.4 \cdot 10^{-7}$$

TIP > Actual
 \therefore ppt will form