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?

Day 1

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 $Al_2(SO_4)_3$?

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

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

ppt = $CaSO_4$ $\quad K_{sp} = 7.1 \cdot 10^{-5}$ (from table)

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

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

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

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

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

$[AgNO_3] = ?$

ppt = Ag_2CrO_4 $\quad K_{sp} = 1.1 \cdot 10^{-12}$ (from table)

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

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

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

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

$AgNO_3 \rightleftharpoons Ag^+ + NO_3^-$

$\boxed{6.1 \cdot 10^{-5} M}$ $\quad 6.1 \cdot 10^{-5}$

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

$CaCl_2 = 1.75\,g$ in $10.0\,L$

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

$CaCO_{3(s)} \rightleftharpoons Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$

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

$CaCl_2 \rightleftharpoons Ca^{2+} + 2Cl^-$

$1.58 \cdot 10^{-3} M \quad 1.58 \cdot 10^{-3} M$

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

$5.0 \cdot 10^{-9} = (1.58 \cdot 10^{-3})[CO_3^{2-}]$

$\boxed{[CO_3^{2-}] = 3.2 \cdot 10^{-6} M}$

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

$[Al_2(SO_4)_3] = ?$

$3\,BaCl_2 + Al_2(SO_4)_3 \rightleftharpoons 3BaSO_4 + 2AlCl_3$

15.0 g solute $\quad$ 2.5 L solvent $\quad$ ppt!

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

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

$BaCl_2 \rightleftharpoons Ba^{2+} + 2Cl^-$

$0.0288 M \quad 0.0288 M$

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

$[SO_4^{2-}] = 3.8 \cdot 10^{-9} M$

$Al_2(SO_4)_3 \rightleftharpoons 2Al^{3+} + 3SO_4^{2-}$

$\boxed{1.3 \cdot 10^{-9} M} \quad \div 3 \quad 3.8 \cdot 10^{-9} M$

5. $AgNO_3 = 5.00\,g \Longrightarrow [NaBrO_3] = 2.5 \cdot 10^{-2} M$

volume of $AgNO_3$ = ?

1:1 ratio

ppt = $AgBrO_3$ / $K_{sp} = 5.3 \cdot 10^{-5} = [Ag^+][BrO_3^-]$

$2.5 \cdot 10^{-2} M$

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

$AgNO_3 \rightleftharpoons Ag^+ + NO_3^-$

$2.1 \cdot 10^{-3} M \quad 2.1 \cdot 10^{-3} M$

$$5.00\,g\,AgNO_3 \times \frac{1\,mol}{169.9\,g} \times \frac{1\,L}{2.1 \cdot 10^{-3}\,mol} = \boxed{14\,L}$$

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

6. $CuCl_2$ mass = ?

$[NaIO_3] = 0.025 M$ 100.0 L

$CuCl_2 + NaIO_3 \rightleftharpoons Cu(IO_3)_{2(s)} + NaCl$

$0.025 M$ ppt

$K_{sp} = [Cu^{2+}][IO_3^-]^2 = 6.9 \cdot 10^{-8}$

1:1 ratio

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

$CuCl_2 \rightleftharpoons Cu^{2+} + 2Cl^-$

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

$$?\,g\,CuCl_2 = \frac{1.1 \cdot 10^{-4}\,mol}{L} \times \frac{100.0\,L}{1} \times \frac{134.2\,g}{1\,mol} = \boxed{1.5\,g}$$

7. $[Na_2SO_4] = 0.0350M$ $\quad = ?\ L$ $\qquad SrSO_4$ ppt

$Sr(NO_3)_2 = 1.25g$

$Na_2SO_4 + Sr(NO_3)_2 \rightleftharpoons SrSO_4(s) + 2NaNO_3$

Na_2SO_4: 0.0350M, ? L $\qquad$ $Sr(NO_3)_2$: 1.25g $\qquad$ $SrSO_4$: ppt

1:1 ratio

$K_{sp} = 3.4 \cdot 10^{-7} = [Sr^{2+}][SO_4^{2-}]$

$[Sr^{2+}] = \frac{3.4 \cdot 10^{-7}}{0.0350M} = 9.7 \cdot 10^{-6}M$

$Sr(NO_3)_2 \rightleftharpoons Sr^{2+} + 2NO_3^-$

$Sr(NO_3)_2$: $9.7 \cdot 10^{-3}M$ $\qquad$ Sr^{2+}: $9.7 \cdot 10^{-6}M$

$$1.25g\ Sr(NO_3)_2 \times \frac{1\ mol}{211.6g} \times \frac{1\ L}{9.7 \cdot 10^{-6}\ mol} = \boxed{609\ L}$$

Day 1

8. $2.50g\ Na_2CrO_4$

$$[Na_2CrO_4] = [CrO_4^{2-}] = \frac{2.50g}{1} \times \frac{1\ mol}{162g} \times \frac{1}{50.0L} = 3.09 \cdot 10^{-4}M$$

(1:1 ratio)

$1.25g\ BaCl_2$

$$[BaCl_2] = [Ba^{2+}] = \frac{1.25g}{1} \times \frac{1\ mol}{208.3g} \times \frac{1}{50.0L} = 1.20 \cdot 10^{-4}M$$

(1:1 ratio)

$TIP = [Ba^{2+}][CrO_4^{2-}] = (1.20 \cdot 10^{-4})(3.09 \cdot 10^{-4})$

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

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

Trial > Actual

∴ Solution is saturated

(past saturation & ppt will form)

9. $MgCl_2 + Cs_2CO_3 \rightleftharpoons MgCO_{3(s)} + CsCl$

$MgCl_2 \rightleftharpoons Mg^{2+} + 2Cl^-$

$4.6\cdot10^{-3}M \rightarrow 4.6\cdot10^{-3}M$

$C_1V_1 = C_2V_2$

$(2.0\cdot10^{-2})(750.0) = C_2(3250)$

$C_2 = 4.6\cdot10^{-3}M$

$Cs_2CO_3 \rightleftharpoons 2Cs^+ + CO_3^{2-}$

$7.7\cdot10^{-3}M \rightarrow 7.7\cdot10^{-3}M$

$C_1V_1 = C_2V_2$

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

$C_2 = 7.7\cdot10^{-3}M$

$TIP = [Mg^{2+}][CO_3^{2-}]$

$= (4.6\cdot10^{-3})(7.7\cdot10^{-3})$

$= 3.5\cdot10^{-5}$

Actual $K_{sp} = 6.8\cdot10^{-6}$

TIP > Actual

∴ ppt will form

10. $Sr(NO_3)_2 + Na_2C_2O_4 \rightleftharpoons NaNO_3 + SrC_2O_{4(s)}$

$Sr(NO_3)_2 \rightleftharpoons Sr^{2+} + 2NO_3^-$

$2.3\cdot10^{-4}M \rightarrow 2.3\cdot10^{-4}M$

$C_1V_1 = C_2V_2$

$(2.5\cdot10^{-3})(250) = C_2(2750)$

$C_2 = 2.3\cdot10^{-4}M$

$Na_2C_2O_4 \rightleftharpoons 2Na^+ + C_2O_4$

$2.7\cdot10^{-4}M \rightarrow 2.7\cdot10^{-4}M$

$C_1V_1 = C_2V_2$

$(3.00\cdot10^{-4})(2500) = C_2(2750)$

$C_2 = 2.7\cdot10^{-4}M$

$TIP = [Sr^{2+}][C_2O_4^{2-}]$

$= (2.3\cdot10^{-4})(2.7\cdot10^{-4})$

$= 6.2\cdot10^{-8}$

Actual $K_{sp} = 4.00\cdot10^{-7}$

TIP < Actual

∴ ppt will <u>not</u> form

11. $Pb(NO_3)_2 + CaCl_2 \rightleftharpoons PbCl_{2(s)} + Ca(NO_3)_2$

$Pb(NO_3)_2 \rightleftharpoons Pb^{2+} + 2NO_3^-$

$0.125M \quad 0.125M$

$C_1V_1 = C_2V_2$

$(0.500)(250.0) = C_2(1000)$

$C_2 = 0.125M$

$CaCl_2 \rightleftharpoons Ca^{2+} + 2Cl^-$

$0.01875M \quad (\times 2) \quad 0.0375M$

$C_1V_1 = C_2V_2$

$(0.0250)(750.0) = C_2(1000)$

$C_2 = 0.01875M$

$TIP = [Pb^{2+}][Cl^-]^2$

$= (0.125)(0.0375)^2$

$= 1.76 \cdot 10^{-4}$

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

TIP > Actual

∴ ppt will form

12. $SrCl_2 + Al_2(SO_4)_3 \rightleftharpoons SrSO_{4(s)} + AlCl_3$

$SrCl_2 \rightleftharpoons Sr^{2+} + 2Cl^-$

$6.00 \cdot 10^{-3}M \quad 6.00 \cdot 10^{-3}M$

$C_1V_1 = C_2V_2$

$(1.20 \cdot 10^{-2})(500) = C_2(1000)$

$C_2 = 6.00 \cdot 10^{-3}M$

$Al_2(SO_4)_3 \rightleftharpoons 2Al^{3+} + 3SO_4^{2-}$

$4.00 \cdot 10^{-3}M \quad (\times 3) \quad 0.0120M$

$C_1V_1 = C_2V_2$

$(8.00 \cdot 10^{-3})(500) = C_2(1000)$

$C_2 = 4.00 \cdot 10^{-3}M$

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

$= (6.00 \cdot 10^{-3})(0.0120)$

$= 7.20 \cdot 10^{-5}$

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

TIP > Actual

∴ ppt will form