Name ____________________________
Date ______________________________

Chemistry 12

Extra Solubility Problems (ESP)

Do as many of these problems as you can and check your answers with the key. Get help on any you don't understand. This sheet contains most of the major types of problems found in Unit 3—Solubility.

1. It is found that 1.892×10^{-13} grams of the compound cadmium (II) sulphide (CdS) will dissolve in 350.0 mL of water to form a saturated solution. Using this data, calculate the value for the Ksp of CdS. Show all of your steps clearly.

2. Calculate the maximum mass of $Mg(OH)_2$ which will dissolve in 150.0 mL of water. Show all of your steps clearly.

3. Calculate the molar solubility of calcium oxalate (CaC_2O_4). Show all of your steps clearly.

4. If 250.0 mL of 0.000340M $Cu(NO_3)_2$ is mixed with 350.0 mL of 3.12×10^{-4}M KIO_3, will a precipitate form? Show all of your steps clearly.

5. Calculate the maximum $[F^-]$ that can exist in a solution in which $[Sr^{2+}] = 0.00050$ M. Show all of your steps clearly.

6. Calculate the mass of Na_2CO_3 that must be added to 2.50 L of 0.00085 M $MgCl_2$ in order to just start precipitation. Show all of your steps clearly.

7. A sample of a saturated solution of MgF_2 was evaporated and the following data table was constructed:

Mass of empty evaporating dish	78.5418 g
Mass of evaporating dish and MgF_2 residue after evaporation	78.5434 g
Volume of saturated MgF_2	100.00 mL
Temperature	25.0 °C

Use this data to calculate the value of Ksp for MgF_2 at 25 °C. Show all of your steps clearly.

8. Calculate the $[Ag^+]$ required to just start precipitation of Ag_2CO_3 in a 0.0030 M solution of $(NH_4)_2CO_3$.

9. A solution is prepared by mixing 20.0 mL of 0.60 M Na_2SO_4 with 60.0 mL of 1.1 M NaOH. Calculate the $[Na^+]$ in the final mixture.

10. The molar solubility of nickel (II) sulphide is 3.317×10^{-11} M. Calculate the value of the solubility product for nickel (II) sulphide. Show all of your work clearly.

11. A solution of potassium chloride is titrated with 0.200 M silver nitrate solution. The following data table was obtained:

	Trial 1	**Trial 2**	**Trial 3**
Initial $AgNO_3$ burette reading (mL)	0.00	5.26	14.63
Final $AgNO_3$ burette reading (mL)	5.26	12.19	19.87
Volume of KCl titrated	25.0	25.0	25.0

Use the information in the data table to calculate the $[Cl^-]$ in the KCl solution. Show all of your work clearly.

Chemistry 12 *Extra Solubility Problems (ESP)*

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1. It is found that 1.892×10^{-13} grams of the compound cadmium (II) sulphide (CdS) will dissolve in 350.0 mL of water to form a saturated solution. Using this data, calculate the value for the Ksp of CdS. Show all of your steps clearly.

g → mol → M → Ksp

$1.892\times10^{-13}\,g\ CdS \times \frac{1\,mol}{144.5\,g} = 1.309\times10^{-15}\,mol$

$M = \frac{1.309\times10^{-15}\,mol}{0.3500\,L} = 3.741\times10^{-15}\,M$ (molar solubility)

$CdS_{(s)} \rightleftarrows Cd^{2+} + S^{2-}$

$-3.741\times10^{-15}\,M \quad +3.741\times10^{-15}\,M \quad +3.741\times10^{-15}\,M$

$K_{sp} = [Cd^{2+}][S^{2-}] = (3.741\times10^{-15})^2 = \boxed{1.399\times10^{-29}}$

2. Calculate the maximum mass of $Mg(OH)_2$ which will dissolve in 150.0 mL of water. Show all of your steps clearly.

Ksp → M → mol → g

$Mg(OH)_{2(s)} \rightleftarrows Mg^{2+} + 2OH^-$ ($-s$, $+s$, $+2s$)

$K_{sp} = [Mg^{2+}][OH^-]^2 = s(2s)^2$

$K_{sp} = 4s^3$

$s = \sqrt[3]{\frac{K_{sp}}{4}} = \sqrt[3]{\frac{5.6\times10^{-12}}{4}} = 1.119\times10^{-4}\,M$

$mol = M \times L = 1.119\times10^{-4}\,M \times 0.1500\,L = 1.678\times10^{-5}\,mol$

$mass = 1.678\times10^{-5}\,mol \times \frac{58.3\,g}{1\,mol} = \boxed{9.8\times10^{-4}\,g}$

3. Calculate the molar solubility of calcium oxalate (CaC_2O_4). Show all of your steps clearly.

$CaC_2O_{4(s)} \rightleftarrows Ca^{2+} + C_2O_4^{2-}$ ($-s$, $+s$, $+s$)

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

$K_{sp} = s^2$

$s = \sqrt{K_{sp}} = \sqrt{2.3\times10^{-9}} = \boxed{4.8\times10^{-5}\,M}$

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4. If 250.0 mL of 0.000340M $Cu(NO_3)_2$ is mixed with 350.0 mL of 3.12×10^{-4}M KIO_3, will a precipitate form? Show all of your steps clearly.

Possible ppt is $Cu(IO_3)_2$ ($Cu(IO_3)_{2(s)} \rightleftarrows Cu^{2+} + 2IO_3^-$)

$[Cu^{2+}] = 3.40\times10^{-4}M \times \frac{250.0\ mL}{600.0\ mL} = 1.417\times10^{-4}M$

$[IO_3^-] = 3.12\times10^{-4}M \times \frac{350.0\ mL}{600.0\ mL} = 1.82\times10^{-4}M$

Trial $K_{sp} = [Cu^{2+}][IO_3^-]^2$
$= (1.417\times10^{-4})(1.82\times10^{-4})^2 = 4.69\times10^{-12}$

Trial ksp < Ksp
$4.69\times10^{-12} < 6.9\times10^{-8}$ so NO PRECIPITATE

5. Calculate the maximum [F⁻] that can exist in a solution in which $[Sr^{2+}] = 0.00050$ M. Show all of your steps clearly.

$SrF_{2(s)} \rightleftarrows Sr^{2+} + 2F^-$

$K_{sp} = [Sr^{2+}][F^-]^2$

$[F^-]^2 = \frac{K_{sp}}{[Sr^{2+}]}$ or $[F^-] = \sqrt{\frac{K_{sp}}{[Sr^{2+}]}} = \sqrt{\frac{4.3\times10^{-9}}{5.0\times10^{-4}}} = 2.9\times10^{-3}M$

6. Calculate the mass of Na_2CO_3 that must be added to 2.50 L of 0.00085 M $MgCl_2$ in order to just start precipitation. Show all of your steps clearly.

ppt is $MgCO_3$

$MgCO_{3(s)} \rightleftarrows Mg^{2+} + CO_3^{2-}$

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

$[CO_3^{2-}] = \frac{K_{sp}}{[Mg^{2+}]} = \frac{6.8\times10^{-6}}{8.5\times10^{-4}} = 8.0\times10^{-3}M$

$[Na_2CO_3] = [CO_3^{2-}] = 8.0\times10^{-3}M$

moles $= 8.0\times10^{-3}M \times 2.50L = 2.0\times10^{-2}mol$

mass $Na_2CO_3 = 2.0\times10^{-2}mol \times \frac{106.0g}{1\ mol} = 2.1\ g$

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7. A sample of a saturated solution of MgF_2 was evaporated and the following data table was constructed:

Mass of empty evaporating dish	78.5418 g
Mass of evaporating dish and MgF_2 residue after evaporation	78.5434 g
Volume of saturated MgF_2	100.00 mL
Temperature	25.0 °C

Use this data to calculate the value of Ksp for MgF_2 at 25 °C. Show all of your steps clearly.

mass of MgF_2 = 78.5434 − 78.5418 = 0.0016 g (4 dp's) (2 SD's)

moles of MgF_2 = $0.0016\text{ g} \times \frac{1\text{ mol}}{62.3\text{ g}} = 2.568\times10^{-5}$ mol

$M = \frac{mol}{L} = \frac{2.568\times10^{-5}\text{ mol}}{0.10000\text{ L}} = 2.568\times10^{-4}$ M

-2.568×10^{-4} M $+2.568\times10^{-4}$ M 5.136×10^{-4} M

$MgF_{2(s)} \rightleftharpoons Mg^{2+} + 2F^-$

$K_{sp} = [Mg^{2+}][F^-]^2 = (2.568\times10^{-4})(5.136\times10^{-4})^2$

$K_{sp} = 6.8\times10^{-11}$

8. Calculate the $[Ag^+]$ required to just start precipitation of Ag_2CO_3 in a 0.0030 M solution of $(NH_4)_2CO_3$.

$Ag_2CO_{3(s)} \rightleftharpoons 2Ag^+ + CO_3^{2-}$

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

$[Ag^+] = \sqrt{\frac{K_{sp}}{[CO_3^{2-}]}} = \sqrt{\frac{8.5\times10^{-12}}{3.0\times10^{-3}}} = 5.3\times10^{-5}$ M

9. A solution is prepared by mixing 20.0 mL of 0.60 M Na_2SO_4 with 60.0 mL of 1.1 M NaOH. Calculate the $[Na^+]$ in the final mixture.

$[Na_2SO_4] = 0.60\text{ M} \times \frac{20.0\text{ mL}}{80.0\text{ mL}} = 0.15$ M

0.15M 0.30M 0.15M

$Na_2SO_{4(s)} \rightarrow 2Na^+ + SO_4^{2-}$

$[NaOH] = 1.1\text{ M} \times \frac{60.0\text{ mL}}{80.0\text{ mL}} = 0.825$ M

0.825M 0.825M 0.825M

$NaOH_{(s)} \rightarrow Na^+ + OH^-$

Final $[Na^+]$ = 0.30 + 0.825 = 1.125 M

$[Na^+] = 1.1$ M (2 SD's)

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10. The molar solubility of nickel (II) sulphide is 3.317×10^{-11} M. Calculate the value of the solubility product for nickel (II) sulphide. Show all of your work clearly.

$$\underset{-3.317\times10^{-11}\,M}{NiS_{(s)}} \rightleftharpoons \underset{+3.317\times10^{-11}\,M}{Ni^{2+}} + \underset{+3.317\times10^{-11}\,M}{S^{2-}}$$

$$K_{sp} = [Ni^{2+}][S^{2-}]$$

$$K_{sp} = (3.317\times10^{-11})^2 = \boxed{1.100\times10^{-21}}$$

11. A solution of potassium chloride is titrated with 0.200 M silver nitrate solution. The following data table was obtained:

	Trial 1	Trial 2	Trial 3
Initial $AgNO_3$ burette reading (mL)	0.00	5.26	14.63
Final $AgNO_3$ burette reading (mL)	5.26	12.19	19.87
Volume of KCl titrated	25.0	25.0	25.0

Use the information in the data table to calculate the [Cl⁻] in the KCl solution. Show all of your work clearly.

	Trial 1	Trial 2	Trial 3
Vol. $AgNO_3$ used (mL)	5.26	6.93 ← DISCARD	5.24

Best average volume $= \frac{5.26 + 5.24}{2} = 5.25\ mL$

$= 0.00525\ L\ AgNO_3$

moles of $AgNO_3$ $= 0.200\,M \times 0.00525\,L = 0.00105$ mol $AgNO_3$ (Ag^+)

$$AgNO_3 + KCl \rightarrow AgCl + KNO_3$$

moles KCl $= 0.00105\ mol\ AgNO_3 \times \frac{1\ mol\ KCl}{1\ mol\ AgNO_3}$

$= 0.00105$ mol KCl

$$[Cl^-] = [KCl] = \frac{0.00105\ mol}{0.0250\ L} = \boxed{0.0420\ M}$$