Solutions Practice Questions

A. Calculating Solubility

1. a) $Ba(OH)_{2(s)} \rightleftharpoons Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$

$K_{sp} = [Ba^{2+}][OH^-]^2$

b) $Ag_3PO_{4(s)} \rightleftharpoons 3Ag^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

$K_{sp} = [Ag^+]^3[PO_4^{3-}]$

2. $CaF_{2(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2F^-_{(aq)}$

	$CaF_{2(s)}$	$Ca^{2+}_{(aq)}$	$2F^-_{(aq)}$
I		0	0
C		$+x$	$+2x$
E		x	$2x$

3. $AgBr_{(s)} \rightleftharpoons Ag^+_{(aq)} + Br^-_{(aq)}$

	$AgBr_{(s)}$	$Ag^+_{(aq)}$	$Br^-_{(aq)}$
I		0	0
C (= solubility)	$-x$	$+x$	$+x$
E		x	x

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

$5.0 \times 10^{-13} = x^2$

$x = 7.1 \times 10^{-7}$

a) $\therefore$ solubility is 7.1×10^{-7} mol/L

b) $m = (7.1 \times 10^{-7})(187.8) = 1.3 \times 10^{-4}$ g

sol'y $= 1.3 \times 10^{-4}$ g/L or 1.3×10^{-5} g/100 mL

4. $SrCrO_{4(s)} \rightleftharpoons Sr^{2+}_{(aq)} + CrO_4^{2-}{}_{(aq)}$

	$SrCrO_{4(s)}$	$Sr^{2+}_{(aq)}$	$CrO_4^{2-}{}_{(aq)}$
I		0	0
C	$\cancel{-x}$	$+x$	$+x$
E		x	x.

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

$3.6 \times 10^{-5} = x^2$

$x = 6.0 \times 10^{-3}$

$\therefore$ sol'y of $SrCrO_4$ is 6.0×10^{-3} mol/L

$PbF_{2\,(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2F^-_{(aq)}$

	$PbF_{2\,(s)}$	$Pb^{2+}_{(aq)}$	$2F^-_{(aq)}$
I		0	0
C	$\cancel{-x}$	$+x$	$+2x$
E		x	$2x$

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

$4.0 \times 10^{-8} = (x)(2x)^2$

$4.0 \times 10^{-8} = 4x^3$

$1.0 \times 10^{-8} = x^3$

$x = 2.2 \times 10^{-3}$

$\therefore$ the sol'y of PbF_2 is 2.2×10^{-3} mol/L

$\therefore$ $SrCrO_4$ has the greatest sol'y.

5. $Ca_3(PO_4)_{2\,(s)} \rightleftharpoons 3Ca^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$

	$Ca_3(PO_4)_{2\,(s)}$	$3Ca^{2+}_{(aq)}$	$2PO_4^{3-}{}_{(aq)}$
I		0	0
C	$\cancel{-x}$	$+3x$	$+2x$
E		$3x$	$2x$

$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$

$1.3 \times 10^{-32} = (3x)^3(2x)^2$

$1.3 \times 10^{-32} = 108x^5$

$\frac{1.3 \times 10^{-32}}{108} = x^5$

$x = 1.6 \times 10^{-7}$

$\therefore$ the molar sol'y of $Ca_3(PO_4)_2$ is 1.6×10^{-7} mol/L

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

	$CaSO_{4(s)}$	$Ca^{2+}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$
I		0	0
C	$-x$	$+x$	$+x$
E		x	x

$6.1 \times 10^{-5} = x^2$

$x = 7.8 \times 10^{-3}$

$\therefore$ sol'y is 7.8×10^{-3} mol/L

sol'y in g/250mL : $7.8 \times 10^{-3} \cancel{mol}/\cancel{L} \times 136.14\, g/\cancel{mol} \times 0.250\cancel{L}$

$=$ ~~0.266 g~~ 0.27 g

$\therefore$ 0.27 g of $CaSO_4$ is dissolved in 250 mL of the saturated sol'n.

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

	$Ca(OH)_{2(s)}$	$Ca^{2+}_{(aq)}$	$2OH^-_{(aq)}$
I		0	0
C	$-x$	$+x$	$+2x$
E		x	$2x$

$1.3 \times 10^{-6} = (x)(2x)^2$

$1.3 \times 10^{-6} = 4x^3$

$x = 6.9 \times 10^{-3}$

$\therefore [OH^-] = 2(6.9 \times 10^{-3}) = 0.014$ mol/L

B. Calculating Ksp

8. $$SrSO_{4(s)} \rightleftharpoons Sr^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$$ $x = 5.8 \times 10^{-4}$

	$SrSO_{4(s)}$	$Sr^{2+}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$
		0	0
molar soly.	$\cancel{(-5.8 \times 10^{-4})}$	$+5.8 \times 10^{-4}$	$+5.8 \times 10^{-4}$
		5.8×10^{-4}	5.8×10^{-4}

$$K_{sp} = [Sr^{2+}][SO_4^{2-}]$$
$$= (5.8 \times 10^{-4})^2 = 3.4 \times 10^{-7}$$

9. $$CuBr_{2(s)} \rightleftharpoons Cu^{2+}_{(aq)} + 2Br^-_{(aq)}$$

	$CuBr_{2(s)}$	$Cu^{2+}_{(aq)}$	$2Br^-_{(aq)}$
		0	0
	$\cancel{(-x)}$	$+x$	$+2x$
		x	$2x$
		(2.0×10^{-4})	(4.0×10^{-8})

$x = 2.0 \times 10^{-4}$ mol/L

$$K_{sp} = [Cu^{2+}][Br^-]^2$$
$$= (x)(2x)^2$$
$$= 4x^3$$
$$= 4(2.0 \times 10^{-4})^3$$
$$= 3.2 \times 10^{-11}$$

or

$$K_{sp} = (2.0 \times 10^{-4})(4.0 \times 10^{-8})^2$$
$$= 3.2 \times 10^{-11}$$

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

	Fe^{2+}	OH^-
	0	0
	$+x$	$+2x$
	x	$2x$
	1.6×10^{-5}	3.2×10^{-5}

$$x = \frac{1.4 \times 10^{-3} \cancel{g}/L}{89.87 \cancel{g}/mol} = 1.6 \times 10^{-5} \text{ mol/L}$$

$$K_{sp} = (1.6 \times 10^{-5})(3.2 \times 10^{-5})^2 = 1.6 \times 10^{-14}$$

11. $Li_2CO_{3(s)} \rightleftharpoons 2Li^+_{(aq)} + CO_3^{2-}{}_{(aq)}$

	Li^+	CO_3^{2-}
	0	0
	$+2x$	$+x$
	$2x$	x
	$2(0.203)$	0.203

$$n = \frac{3.75g}{73.89} = 0.0508 \text{ mol}$$

$$x = \frac{n}{V} = \frac{0.0508 \text{ mol}}{0.250 \text{ L}} = 0.203 \text{ mol/L}$$

$$K_{sp} = (0.406)^2(0.203) = 0.0335$$

C. The Nature of Solutions.

12. $Ag_2SO_{4(s)} \rightleftharpoons 2Ag^+_{(aq)} + SO_4^{2-}{}_{(aq)}$ $K_{sp} = 1.2 \times 10^{-5}$

I $\quad 0.0010 \quad 0.0050$

$Q = (0.0010)^2(0.0050) = 5.0 \times 10^{-9}$

$Q < K_{sp}$ ∴ the solution is unsaturated.

13. $NiCO_{3(s)} \rightleftharpoons Ni^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$ $K_{sp} = 1.4 \times 10^{-7}$

I $\quad 0.010 \quad 0.00050$

$Q = (0.010)(0.00050) = 5.0 \times 10^{-6}$

$Q > K_{sp}$ ∴ the solution is supersaturated.

14. $BaCO_{3(s)} \rightleftharpoons Ba^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$ $K_{sp} = 1.6 \times 10^{-9}$

$\quad 2.0 \times 10^{-5} \quad 4.0 \times 10^{-5}$

$Q = (2.0 \times 10^{-5})(4.0 \times 10^{-5}) = 8.0 \times 10^{-10}$

$Q < K_{sp}$ ∴ the solution is unsaturated.

D. Will a Precipitate Form?

15. $AgOH_{(s)} \rightleftharpoons Ag^+_{(aq)} + OH^-_{(aq)}$ $K_{sp} = 2.0 \times 10^{-8}$

$\qquad 0.010 \qquad 0.050$

$Q = (0.010)(0.050) = 5.0 \times 10^{-4}$

$Q > K_{sp}$ ∴ yes a ppte will form.

16. Which ppte? Na^+ + NO_3^- are always spectator ions ∴ will a ppte of $PbCl_2$ form?

$PbCl_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$ $K_{sp} = 1.6 \times 10^{-5}$

$\qquad 0.0010 \qquad 0.050$

* Both sol'ns have been diluted in half ∴ $[Pb^{2+}]$ will be 0.0010M + $[Cl^-]$ will be 0.050M.

see note below

$Q = (0.0010)(0.050)^2 = 2.5 \times 10^{-6}$

$Q < K_{sp}$ ∴ no a ppte will NOT form.

NOTE:

$[NaCl] = [Cl^-]$ using $C_1V_1 = C_2V_2$

$(100)(0.10) = C_2(200)$

$C_2 = 0.050$

$[Pb(NO_3)] = [Pb^{2+}]$ using $C_1V_1 = C_2V_2$

$(0.0020)(100) = C_2(200)$

$C_2 = 0.0010$

17. $Ag_2SO_{4(s)} \rightleftharpoons 2Ag^+_{(aq)} + SO_4^{2-}{}_{(aq)}$ $K_{sp} = 1.2 \times 10^{-5}$

0.00030 0.0090

$[AgNO_3] = [Ag^+]$: $C_1V_1 = C_2V_2$
$(0.0030)(10.0) = C_2(100.0)$
$C_2 = 0.00030$

or Dilution factor $= \frac{1}{10}$th. for Ag^+

$\therefore [Ag^+) = \frac{0.0030}{10}$

$= 0.00030$

$[Na_2SO_4] = [SO_4^{2-}]$: $(0.010)(90.0) = C_2(100.0)$
$C_2 = 0.0090$

Dil'n factor for $SO_4^{2-} = 9/10$
or 90%.
$[SO_4^{2-}] = (0.90)(0.010)$
$= 0.0090\ M$

$Q = (0.00030)^2(0.0090)$
$= 8.1 \times 10^{-10}$

$Q < K_{sp}$ $\therefore$ NO a ppte will NOT form.

18. $AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$ $K_{sp} = 1.5 \times 10^{-16}$

0.0067 0.00099

$[AgNO_3] = [Ag^+]$: $(0.010)(100) = C_2(150)$
$C_2 = 0.0067\ M$

or use 2/3 dil'n (67%)

~~$[Cl^-]$~~ $\neq [AlCl_3]$: $(0.0010)(50) = C_2(150)$
$C_2 = 0.00033\ M$

or use 1/3 dil'n (33%)

$[Cl^-] = 3(0.00033) = 0.00099\ M$

$Q = (0.0067)(0.00099) = 6.6 \times 10^{-6}$ $Q > K_{sp}$ $\therefore$ YES!

E. How Much Precipitate Will Form?

19. $[Ni^{2+}]$: $\frac{0.010}{2} = 0.0050\ M$ (½ or 50% dil'n)

$[CO_3^{2-}] = \frac{0.020}{2} = \cancel{0.0050\ M}$ 0.010 M (50% dil'n)

$\longleftarrow$

$$NiCO_{3(s)} \rightleftharpoons Ni^{2+}_{(aq)} + CO^{2-}_{3(aq)} \quad K_{sp} = 1.4 \times 10^{-7}$$

	$NiCO_{3(s)}$	$Ni^{2+}_{(aq)}$	$CO^{2-}_{3(aq)}$
I		0.0050	0.010
C	+x	−x	−x
E		0.0050−x	0.010−x

= moles/L of ppte.

$Q = (0.0050)(0.010)$
$= 5.0 \times 10^{-5}$
$Q > K_{sp}$ ∴ it will ppte.

$1.4 \times 10^{-7} = (0.0050 - x)(0.010 - x)$
$1.4 \times 10^{-7} = 5.0 \times 10^{-5} - 0.015x + x^2$
$x^2 - 0.015x + {}^{*}5.0 \times 10^{-5} = 0$
$x = 0.010$ or 0.0050

↑
too large

*NOTE:
$5.0 \times 10^{-5} - 1.4 \times 10^{-7}$
$= 4.986 \times 10^{-5}$
to 2 significant digits $= 5.0 \times 10^{-5}$

$m = 0.0050\ mol/L \times 1L \times 118.70$
$= 0.59\ g$

20. $FeCO_{3(s)} \rightleftharpoons Fe^{2+}_{(aq)} + CO_{3\,(aq)}^{2-}$ $K_{sp} = 2.0 \times 10^{-11}$

amount of ppte in mol/L

	$FeCO_{3(s)}$	$Fe^{2+}_{(aq)}$	$CO_{3\,(aq)}^{2-}$
I		0.010	0.00080
C	+x	−x	−x
E		0.010−x	0.00080−x

$[Fe^{3+}] = [Fe(NO_3)_2]$ $\frac{100\,mL}{300\,mL} = \frac{1}{3}$ dilution (or 33.3%)
$= \frac{1}{3}(0.030)$
$= 0.010\,M$

$[CO_3^{2-}] = [Na_2CO_3]$ $\frac{200\,mL}{300\,mL} = \frac{2}{3}$ dilution (or 66.7%)
$= \frac{2}{3}(0.00120)$
$= 0.00080\,M$

$K_{sp} = [Fe^{3+}][CO_3^{2-}]$
* $2.0 \times 10^{-11} = (0.010-x)(0.00080-x)$
* this value will become insignificant when terms are collected.
$\therefore\ 0 = (0.010-x)(0.00080-x)$
$x = \cancel{0.010}$ or 0.00080
too large

$\therefore$ amount of ppte $= 0.00080\,mol/L$ - only have 300 mL
$= 0.0008\,mol/L \times 0.300\,L$
$= 2.4 \times 10^{-4}\,mol/300\,mL$
$= 2.4 \times 10^{-4}\,mol \times 115.86\,g/300\,mL$
$= 0.028\,g/300\,mL$

mm of $FeCO_3$

21. $$\begin{array}{lccc} FeCO_{3(s)} \rightleftharpoons & Fe^{2+}_{(aq)} & + & CO_{3}^{2-}{}_{(aq)} \\ & 0.010 & & 0.00080 \\ & -0.00080 & & -0.00080 \\ \hline & 9.2\times10^{-3}\ M & & 0\ * \end{array}$$

* not possible ⇒ value of x must be slightly less than 0.00080 (eliminating Ksp + rounding has contributed to this) (See NOTE below)

To determine $[CO_3^{2-}]$:

$$2.0\times10^{-11} = [Fe^{2+}][CO_3^{2-}]$$
$$2.0\times10^{-11} = (9.2\times10^{-3})[CO_3^{2-}]$$
$$[CO_3^{2-}] = \frac{2.0\times10^{-11}}{9.2\times10^{-3}} = 2.2\times10^{-9}\ M.$$

NOTE: Resolving for x would give us

$$0.00080 - x = 2.2\times10^{-9}$$
$$x = 7.999978\times10^{-4}$$

The difference between this value of x + $x = 0.00080$ is meaningless in terms of the amount of ppte formed + $[Fe^{2+}]$

22. $SrCrO_{4(s)} \rightleftharpoons Sr^{2+}_{(aq)} + CrO_4^{2-}{}_{(aq)}$ $K_{sp} = 3.6 \times 10^{-5}$

	$SrCrO_{4(s)}$	$Sr^{2+}_{(aq)}$	$CrO_4^{2-}{}_{(aq)}$
I		0.0010	0.0020
C	$+x$	$-x$	$-x$
E			

$[Sr^{2+}] = [Sr(NO_3)_2]$ $\qquad \frac{200\,mL}{400\,mL} = \frac{1}{2}$ dilution (50%)
$= 0.0010\,M$

$[CrO_4^{2-}] = [Na_2CrO_4]$ $\qquad \frac{200\,mL}{400\,mL} = \frac{1}{2}$ dilution (50%)
$= 0.0020\,M$

$Q = (0.0010)(0.0020) = 2.0 \times 10^{-6}$
$Q < K_{sp}$ $\therefore$ NONE of the $SrCrO_4$ will precipitate.

~~23.~~ F. COMMON ION

23. $PbSO_{4(s)} \rightleftharpoons Pb^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$ $\qquad [SO_4^{2-}] = [Na_2SO_4] = 0.010M$

	$PbSO_{4(s)}$	$Pb^{2+}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$
I		0	0.010
C	$-x$	$+x$	$+x$
E		x	$0.010+x$

$$1.3 \times 10^{-8} = x(0.010 + x)$$
$$1.3 \times 10^{-8} = 0.010x + x^2$$
$$x^2 + 0.010x - 1.3 \times 10^{-8} = 0$$
$$x = 1.3 \times 10^{-6} \text{ or } \cancel{-0.010}$$

* NOTE – the same answer would have been obtained if the "x" in $0.010 + x$ had been deemed insignificant

#23 cont'd

ie $1.3 \times 10^{-8} = x(0.010)$

$x = 1.3 \times 10^{-6}$

$\therefore [Pb^{2+}] = 1.3 \times 10^{-6}$ M.

24. mass dissolved $= 1.3 \times 10^{-6}$ mol/L $\times$ 1L $\times$ 303.26 g/mol

$= 3.9 \times 10^{-4}$ g

25. $PbBr_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Br^-_{(aq)}$ $K_{sp} = 4.6 \times 10^{-6}$

		Pb^{2+}	Br^-
I		0	0.10
C		$+x$	$+2x$
E		x	$0.10 + 2x$

$[Br^-] = [NaBr]$

$= 0.10$ M

insignificant

$4.6 \times 10^{-6} = x(0.10)^2$

$4.6 \times 10^{-6} = 0.010x$

$x = 4.6 \times 10^{-4}$

$\therefore [Pb^{2+}] = 4.6 \times 10^{-4}$ M

* NOTE - if $2x$ is kept in, we will have to solve a cubic - I did this + got $x = 4.6 \times 10^{-4}$

26. $BaF_{2(s)} \rightleftharpoons Ba^{2+}_{(aq)} + 2F^-_{(aq)}$

Ba^{2+}	F^-
0	0
$+x$	$+2x$
x	$2x$

$2.4 \times 10^{-5} = (x)(2x)^2$

$2.4 \times 10^{-5} = 4x^3$

$x = 0.018$

26. Cont'd

amount dissolved = 0.018 mol/L

= 0.018 mol/L × 0.400 L × 175.30

= 1.26 or $\boxed{1.3\,g}$

27. $BaF_{2(s)} \rightleftharpoons Ba^{2+}_{(aq)} + 2F^-_{(aq)}$

$[Ba^{2+}] = [BaCl_2] = 0.050$

	$Ba^{2+}_{(aq)}$	$2F^-_{(aq)}$
	0.050	0
	+x	+2x
	0.050+x	2x

insignificant.

If the cubic had been solved, x = 0.010 – unlike #25, dismissing "+x" does make a slight difference – this is b/c the Ksp is a little larger in this question.

$2.4 \times 10^{-5} = (0.050)(2x)^2$

$2.4 \times 10^{-5} = (0.050)(4)x^2$

$2.4 \times 10^{-5} = 0.20x^2$

$x^2 = 1.2 \times 10^{-4}$

$x = 0.011$

amount dissolved = 0.011 mol/L

= 0.011 mol/L × 0.400 L × 175.30

= 0.77 g