Monday, January 27, 2014
6:07 PM

Thinking Like a Chemist About Solubility Equilibrium

UNIT 5 DAY 6

What are we going to learn today?

Thinking Like a Chemist in the Context of the Solution Equilbria

Reaction Quotient
Common Ion Effect
Temperature & Solubility & Supersaturated

IMPORTANT INFORMATION

LM10 and LM11 due this morning

LM12 and HW3 due Tue 9AM

Looking ahead:
EXAM 1, Feb 5th 7 – 9 PM
Details of room assignments will be posted on website next week

Independent Quiz:, No talking!

The K_{sp} expression for the dissolution of $Cd_3(PO_4)_2$ is:

A. $K_{sp} = [Cd^{2+}][PO_4^{3-}]$

B. $K_{sp} = [Cd^{2+}]^2[PO_4^{3-}]^2$

C. $K_{sp} = [x]\ [y]$

D. $K_{sp} = [x]^2\ [x]^3$

E. $K_{sp} = [Cd^{2+}]^3[PO_4^{3-}]^2$

Poll: Clicker Question

The net ionic equation for the following is:

$(NH_4)_2CO_{3(aq)} + CaCl_{2(aq)} \rightarrow$

A. $(NH_4)_2CO_3(aq) + CaCl_2(aq) \rightarrow 2NH_4Cl(aq) + CaCO_3(aq)$

B. $(NH_4)_2CO_3(aq) + CaCl_2(aq) \rightarrow 2NH_4Cl(aq) + CaCO_3(s)$

C. $2NH_4^+(aq) + CO_3^{2-}(aq) + Ca^{2+}(aq) + 2Cl^- \rightarrow 2NH_4^+(aq) + 2Cl^-(aq) + CaCO_3(s)$

D. $2NH_4^+(aq) + CO_3^{2-}(aq) + Ca^{2+}(aq) + 2Cl^- \rightarrow CaCO_3(s)$

E. $CO_3^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaCO_3(s)$

A few useful definitions and ideas

Precipitation

Formation of an insoluble solid in solution
(usually form mixing two solutions)

Spectator Ions

Ions that don't participate in the chemistry
(aqueous ions that appear as both reactants and products)

What is soluble?

Many solubility rules
Typically K_{sp} is given for "insoluble" compounds

All Na^+, K^+, and NO_3^- salts are soluble

ACTIVITY – SOLUBILITY II

Mix a solution of lead II nitrate with a solution of potassium iodide
Fully describe:

$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)} + 2KNO_{3(aq)}$

fully describe in words and pictures

2 clear solns mixed
ended up w/ yellow solid suspended in soln → it will settle out as a precipitate

tiny amount of ions in soln

Also → you need to be able to draw nice microscopic pictures on your activity sheet → See key for details.

POLL: Clicker Question

The Ksp of PbI_2 is 1.4×10^{-8}. Predict $[Pb^{2+}]$ and $[I^-]$ in the saturated solution.

A. $[Pb^{2+}] = 4.7 \times 10^{-9}$ $[I^-] = 4.7 \times 10^{-9}$
B. $[Pb^{2+}] = 4.7 \times 10^{-9}$ $[I^-] = 9.3 \times 10^{-9}$
C. $[Pb^{2+}] = 1.5 \times 10^{-3}$ $[I^-] = 3.0 \times 10^{-3}$
D. $[Pb^{2+}] = 8.4 \times 10^{-5}$ $[I^-] = 1.7 \times 10^{-4}$

$PbI_{2(s)} \rightarrow Pb^{2+}_{(aq)} + 2I^-_{(aq)}$

		Pb^{2+}	I^-
Initial	Solid	0	0
Change	$-x$	$+x$	$+2x$
equilibrium	solid $-x$	x	$2x$

$1.4 \times 10^{-8} = [Pb^{2+}][I^-]^2$

$1.4 \times 10^{-8} = (x)(2x)^2$

Add more KI to soln what happens to $[I^-]$? IT GOES UP!

POLL: Clicker Question

The Ksp of PbI_2 is 1.4×10^{-8}. Predict $[Pb^{2+}]$ and $[I^-]$ in

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

POLL: Clicker Question

The Ksp of PbI_2 is 1.4×10^{-8}. Predict $[Pb^{2+}]$ and $[I^-]$ in the saturated solution after the addition of 0.5 moles of KI. in 1 Liter of Soln

A. $[Pb^{2+}] = 1.5 \times 10^{-3}$ $[I^-] = 3.0 \times 10^{-3}$

B. $[Pb^{2+}] = 1.5 \times 10^{-3}$ $[I^-] = 1.5 \times 10^{-3}$

C. $[Pb^{2+}] = 5.6 \times 10^{-8}$ $[I^-] = 0.5$

D. $[Pb^{2+}] = 5.6 \times 10^{-8}$ $[I^-] = 0.25$

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

$PbI_2 \leftrightarrow Pb^{2+} + 2I^-$

initial	solid	0	.5
Chg	$-x$	$+x$	$+2x$
final	solid $-x$	x	$.5+2x$

$1.4 \times 10^{-8} = [x][.5+2x]^2$

x is tiny!

So you can ignore it!

$1.4 \times 10^{-8} = x(.5)^2$

$x = [Pb^{2+}] =$

ion product is constant!

So at equilibrium if one concentration goes up the other must go down

Reaction Quotient, Q

Q is the value of the ion product at any point in a process, not necessarily at the equilibrium ion concentrations.

Q is useful, because you can compare it to the value of K to decide if a precipitate will form.

$Q_{sp} = [Pb^{2+}][I^-]^2$

same form as K_{sp} but not necessarily at equilibrium

$Q_{sp} > K_{sp}$ too high precipitate will form

$Q_{sp} = K_{sp}$ → at equilibrium

$Q_{sp} < K_{sp}$ too low precipitate will not form

POLL: Clicker Question

Reaction Quotient, Q

For AgCl $K_{sp} = [Ag^+]_{eq}[Cl^-]_{eq} = 1.8 \times 10^{-10}$

POLL: Clicker Question

Reaction Quotient, Q

For AgCl $K_{sp} = [Ag^+]_{eq}[Cl^-]_{eq} = 1.8 \times 10^{-10}$

You how a solution such that the instantaneous concentrations of ions gives a $Q_{sp} = [Ag^+][Cl^-] = 1.8 \times 10^{-6}$

Will a precipitate form?
A. Yes
B. No

Is $Q > K$ or is $Q < K$?

That is the question?

$Q_{sp} < K_{sp}$ too low precipitate will not form

POLL: Clicker Question

Mix 1 liter of 0.2 molar of the lead salt with 1 liter of 0.2 molar of the iodide salt.
What is the value of Q_{sp} and will a precipitate form?

A. $Q_{sp} = 1.4 \times 10^{-8}$; no
B. $Q_{sp} = 1.0 \times 10^{-3}$; no
C. $Q_{sp} = 1.0 \times 10^{-3}$; yes
D. $Q_{sp} = 4.0 \times 10^{-3}$; yes

POLL: Clicker Question

What is the mass of the PbI_2 that was precipitated?

A. 461 g PbI_2
B. 46.1 g PbI_2
C. 92.2 g PbI_2
D. Impossible to tell because equilibrium

POLL: Clicker Question

What concentration will the lead ion need to be dropped to to prevent precipitation?

A. 7.0×10^{-9} M

B. 7.0×10^{-8} M

C. 1.4×10^{-10} M

D. 1.4×10^{-6} M

Temperature Dependence of Solubility –

Solubility Increases with T for ENDOTHERMIC solutions

because makes K_{sp} bigger

Solubility Decreases with T for EXOTHERMIC solutions

because makes K_{sp} smaller

DEMONSTRATE

Solubility Increases with T for ENDOTHERMIC solutions

because makes K_{sp} bigger

SUPER SATURATED SOLUTION

METASTABLE SOLUTION

What did we learn today?

Solubility is an equilibrium condition.

Determine the solubility of an insoluble salt in the presence of a common ion.

Q is the reaction quotient and indicates the extent of the reaction.

Learning Outcomes

Calculate solubilities in the presence of a common ion.

Given concentrations of specific ions, predict if a precipitate will form (amount or concentration) using the concept of the reaction quotient, Q.

I have all of these ions in solution, do I get a precipitate?

This is just equilibrium, compare Q to K

K_{sp}= 1.7 x 10^{-5} for $PbCl_2$

I have a solution in which $[Pb^{2+}]$ = 10^{-2} M and $[Cl^-]$ = 10^{-2} M

A. some $PbCl_2$ will precipitate

B. all the $PbCl_2$ will be solution

If I mix a 100 mL of 1 M NaCl solution with a 200 mL of 1 M $AgNO_3$ solution how much solid AgCl will form (K_{sp}= 1.8 x 10^{-10})?

$NaCl(aq) + AgNO_3(aq) \leftrightarrow AgCl(s) + NaNO_3(aq)$

$Ag^+(aq) + Cl^-(aq) \leftrightarrow AgCl(s)$

Assume all the maximum amount of AgCl forms

Need to convert from concentration to moles!

Silver Nitrate ($AgNO_3$) and Sodium Chloride (NaCl) are both soluble salts.

What will happen if I mix 200 mL of 1 M $AgNO_3$ solution with 100 ml of 1 M NaCl solution given that K_{sp} for AgCl is 1.8×10^{-10}

A. I'll have a solution with Ag^+, Cl^-, Na^+, and NO_3^- ions

B. some solid AgCl will form

C. both B & C