Solubility

Our start in adventures in Aqueous Equilibria

Sea Shells are essentially
Calcium Carbonate crystals held together by proteins

Given this information what do you think equilibrium constant will be for this reaction?

$$CaCO_3\,(s) \longleftrightarrow Ca^{2+}(aq) + CO_3^{2-}(aq)$$

A. a number much much less than 1

B. a number approximately equal to 1

C. a number much much larger than 1

We will be mostly dividing substances up

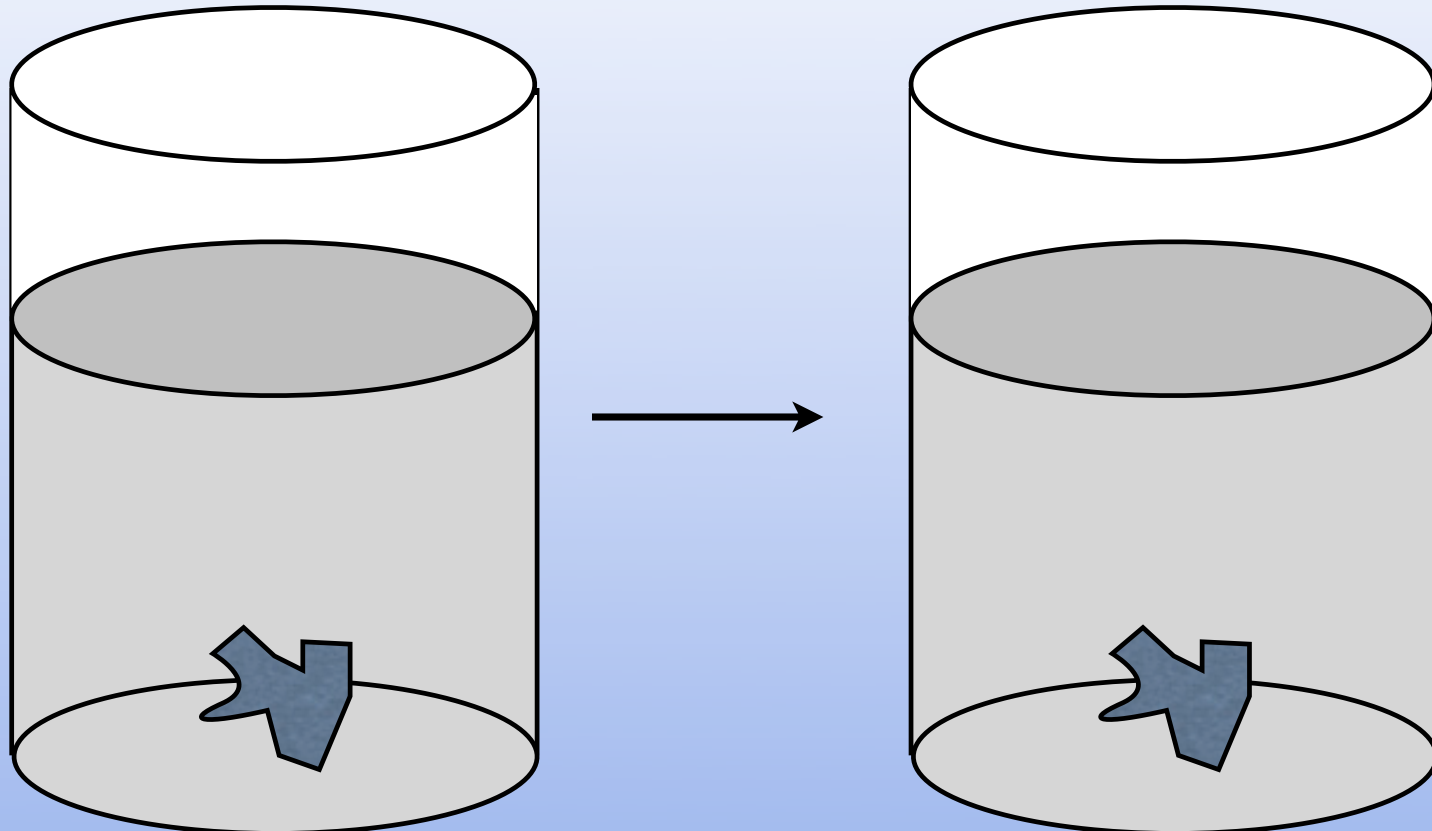
Strong Electrolyte

Weak Electrolyte

Rock Demo

Rock Demo

$[Ca^{2+}] =$ $[Ca^{2+}] =$



How much of the rock dissolved?

How much is very small?
Solubility Equilibria

$$CaCO_3\,(s) \longleftrightarrow Ca^{2+}(aq) + CO_3^{2-}(aq)$$

$$K_{sp} =$$

Solubility is given in practical units

Molar Solubility

Moles of solute that will dissolve in 1 L of sovlent (water)

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Moles of solute that will dissolve in 1 L of sovlent (water)

Solubility

grams of solute that will dissolve in 1 L of sovlent (water)

What is the solubility of AgCl?

$$AgCl\,(s) \longleftrightarrow Ag^{+}(aq) + Cl^{-}(aq)$$

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

Reaction	$AgCl\,(s) \longleftrightarrow Ag^{+}(aq) + Cl^{-}(aq)$
Initial	
Change	
Equilibrium	

What is the solubility of AgCl?

$K_{sp} = [Ag^+][Cl^-] = 6 \times 10^{-9}$

Reaction	$AgCl\ (s) \longleftrightarrow$	$Ag^+(aq)$	$+\ Cl^-(aq)$
Initial		0	0
Change		+x	+x
Equilibrium		+x	+x

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

What is the solubility of AgCl?

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

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

$[Ag^+] = 1.3 \times 10^{-5}$ M

M.W. of AgCl is 143.3 g mol^{-1}

Which of the following compounds has the lowest molar solubility?

A. AgCl $K_{sp} = 1.8 \times 10^{-10}$

B. FeS $K_{sp} = 8 \times 10^{-19}$

C. LiF $K_{sp} = 1.8 \times 10^{-3}$

D. ZnSe $K_{sp} = 2 \times 10^{-25}$

Which of the following compounds has the lowest molar solubility?

A.	$AgCl$	$K_{sp} = 1.8 \times 10^{-10}$
B.	$Cd_3(PO_4)_2$	$K_{sp} = 2.5 \times 10^{-30}$
C.	$Zn(OH)_2$	$K_{sp} = 3 \times 10^{-17}$
D.	$ZnSe$	$K_{sp} = 2 \times 10^{-25}$

What is the concentration of Sr^{2+} in a saturated solution of SrF_2?

$$K_{sp} = [Sr^{2+}][F^-] = 4.3 \times 10^{-9}$$

Reaction	$SrF_2 (s)$ $\longleftrightarrow$	$Sr^{2+}(aq)$ +	$2F^-(aq)$
Initial			
Change			
Equilibrium			

1×10^{-3}

Decent estimate of the molar solubility
count the ions
take that "root" of the K_{sp}

A.	$AgCl$	$K_{sp} = 1.8 \times 10^{-10}$
B.	$Cd_3(PO_4)_2$	$K_{sp} = 2.5 \times 10^{-30}$
C.	$Zn(OH)_2$	$K_{sp} = 3 \times 10^{-17}$
D.	$ZnSe$	$K_{sp} = 2 \times 10^{-25}$

Given that K_{sp} for AgCl is 1.8×10^{-10},
and the NaCl is strong electrolyte

What do you predict for solubility of AgCl in a 1 M NaCl solution?

$K_{sp}=$

A. more soluble than in pure water

B. same solubility as pure water

C. lower solubility than pure water

Given that K_{sp} for AgCl is 1.8×10^{-10},
and the NaCl is strong electrolyte

What is the concentration of Ag^+ in a 1 M NaCl solution
that contains solid AgCl?

$K_{sp}=$

A. 1.8×10^{-10} M

B. 1.8×10^{-6} M

C. 1.3×10^{-5} M

D. 1 M

What is the solubility of AgCl?

$K_{sp} = [Ag^+][Cl^-] = 6 \times 10^{-9}$

Reaction	$AgCl (s) \longleftrightarrow$	$Ag^+(aq)$	$+ Cl^-(aq)$
Initial		0	1
Change		+x	+x
Equilibrium		+x	1+x

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

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

A few useful definitions and ideas

Precipitation

Insoluble solid that forms and drops out of solution

Spectator Ions

Ions that don't participate in the chemistry

What is soluble?

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

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

Ionic Equations

$NaCl(aq) + AgNO_3 (aq)$

$\downarrow$

Net ionic equation

Precipitation Calculations

First take the reaction to completion
then calculate back to the equilibrium

K_{sp} is generally small.
First assume as much solid as possible forms
Then look at what "re-dissolves" into 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!

We assumed as much solid as possible formed
How much "redissolves" to get to equilibrium?

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

Reaction	$AgCl\ (s) \longleftrightarrow$	$Ag^+(aq)$	$+\ Cl^-(aq)$
Initial		0.333	0
Change		+x	+x
Equilibrium		.333+x	+x

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

Selective precipitation

I have a solution which contains
0.1 M $AgNO_3$ and 0.1 M $PbNO_3$.
How can I get out the silver and leave the lead behind?

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Add an anion for an insoluble salt for silver such as Cl^-
K_{sp} is 1.6×10^{-10} for AgCl

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But $PbCl_2$ is also insoluble so it will precipitate out as well
K_{sp} is 2.4×10^{-4} for $PbCl_2$

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The K_{sp} for AgCl is much smaller so we can selectively precipitate the AgCl

I have a solution which contains
0.1 M $AgNO_3$ and 0.1 M $PbNO_3$.
How can I get out the silver and leave the lead behind?

what is the maximum concentration of Cl^-
we can have and still have the $PbCl_2$ dissolved $K_{sp} = 2.4 \times 10^{-4}$

A. 4.9×10^{-2} M

B. 1.2×10^{-4} M

C. 2.4×10^{-4} M

D. 2.4×10^{-3} M

I have a solution which contains
0.1 M $AgNO_3$ and 0.1 M $PbNO_3$.
How can I get out the silver and leave the lead behind?

If the Cl^- concentration is 4.9×10^{-2} M, what is the Ag^+ concentration?
$K_{sp} = 1.6 \times 10^{-10}$ for AgCl

A. 4.9×10^{-12} M

B. 3.2×10^{-9} M

C. 1.6×10^{-10} M

D. 2.4×10^{-3} M

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