

Thinking Like a
Chemist About
Solubility Equilibrium

UNIT5 DAY5

CH302 Vanden Bout/LaBrake Spring 2012

What are we going to learn today?

Thinking Like a Chemist in the
Context of the Solution Equilibria

Concept of Solubility
Modeling Ionic Reactions
Solubility Product Constant

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IMPORTANT INFORMATION

LM09 and HW2 due this morning

LM10 and LM11 due Th 9AM

Looking ahead:

EXAM 1, Feb 6th 7 – 9 PM

Details of room assignments will be posted on
website next week

Version number

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Quiz: Clicker Question 1

When comparing the free energy of the pure solvent to the free energy of a solution formed by adding a solid solute to the solvent, the free energy of the solution is:

- A. Higher
- B. No difference
- C. Lower
- D. Follows no trend, you need to calculate

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Quiz: Clicker Question 2

Which would you expect to have the lowest vapor pressure?

- A. 4 M sugar aqueous solution $i = 1$
- B. 0.75 M KCl aqueous solution $i = 2$
- C. 0.25 M CaCl_2 aqueous solution $i = 3$
- D. 1.5 M MgCl_2 aqueous solution $i = 3$
 $\hookrightarrow 4.5 \text{ M of "bits"}$

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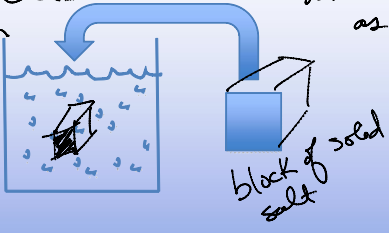
Poll: Clicker Question 3

What will happen if I add more solid salt to a saturated solution? UNITS-DAYS-LaB1230pm Page 2

What will happen if I add more solid salt to a saturated solution?

dissolved as much as we can

*dynamic equilibrium
surface of solid is not static
on = off*



- a. More of the salt will dissolve.
- b. The solution will become less saturated
- c. The concentration of the salt will remain the same.
- d. Need more information, eg the solubility of the salt.

Quantify

Solubility is given in practical units

$\frac{g \text{ solute}}{100 g \text{ solution}}$

amount of solute that will dissolve given amount of solvent or solution

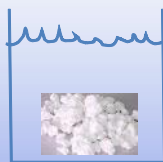
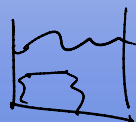
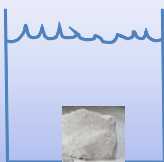
Molar Solubility is the maximum # moles of solute that will dissolve in 1 L ~~solvent~~ ^{solution} at a given temperature

Equilibrium *at saturation*

Rate of solute entering solvent = Rate of solute recrystallizing
Rate off = Rate on

START WORKING ON ACTIVITY

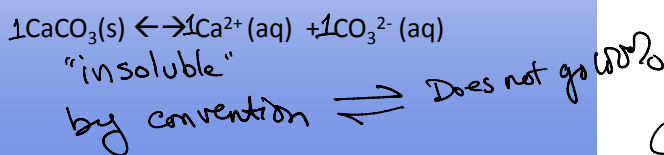
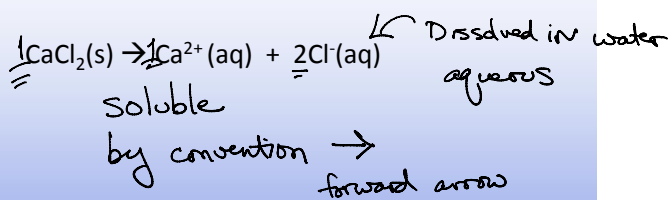
Rock (CaCO_3) in water versus salt (CaCl_2)



How much of the rock dissolved?

- A. None of the rock dissolved
- B. All of the rock dissolved
- C. A tiny amount dissolved

#3 Compare solubilities... model with reaction:
 no water in reactions → does not participate chemically



molar mass

$$\text{CaCl}_2 \quad 111.07 \frac{\text{g}}{\text{mol}} \quad 1.435 \frac{\text{g solution}}{\text{mL solution}}$$

$$\text{NaCl} \quad 58.5 \frac{\text{g}}{\text{mol}}$$

Looking for: molar solubility in solution

Given $\frac{\text{g solute}}{100 \text{g H}_2\text{O}}$
 ↑
 solvent

solution = solute + solvent

$$\text{CaCl}_2 \quad \frac{64.7 \text{ g solute}}{164.7 \text{ g solution}}$$

The molar solubility of CaCl₂ is:

- A. 0.40 M
- B. 0.65 M
- C. 3.6 x 10⁻³ M
- D. 1.5 M
- E. 5.1 M

CaCl₂ Density 1.435 $\frac{\text{g solution}}{\text{mL solution}}$
 MM 111.07

CaCl_2 Density $1.435 \frac{\text{g solution}}{\text{mL solution}}$
 MM $111.07 \text{ g/mol CaCl}_2$
 Solubility $\frac{64.7 \text{ g solute}}{100 \text{ g water}}$

multiply n top
Divide n bottom

$$\frac{64.7 \text{ g CaCl}_2}{164.7 \text{ g solution}} \cdot \frac{1 \text{ mol CaCl}_2}{111.07 \text{ g CaCl}_2} \cdot \frac{1.435 \text{ g CaCl}_2/\text{soln}}{1 \text{ mL soln}} \cdot \frac{1000 \text{ mL}}{1 \text{ L}} = 5.08 \frac{\text{moles}}{\text{liter}}$$

\uparrow molar mass \uparrow Density \uparrow conversion

Nace 5.4 M — Try it on your own!

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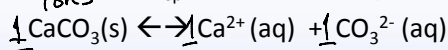
Poll: Clicker Question 6

$K_{sp} = \text{Product of ions}$

each salt has its own!

Bracket shows molar concentration moles/L

$$K_{sp} = 8.7 \times 10^{-9} = [\text{Ca}^{2+}][\text{CO}_3^{2-}]$$



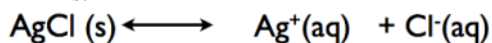
Set up the K_{sp} expression.
Solve for molar solubility of CaCO_3 .

- a. 9.3×10^{-5}
- b. 9.3×10^5
- c. 4.4×10^{-9}
- d. Not enough information
- e. Insoluble means not soluble, so it is 0

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What is the solubility of AgCl ?

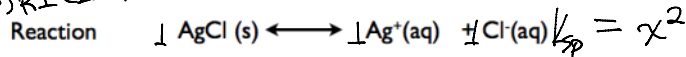
1) Write Reaction



2) Write K_{sp}

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

3) RICE table



Initial	Some	\emptyset	\emptyset	$\sqrt{K_{sp}} = x$
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Change	$-x$	$+x$	$+x$	$x = 1.3 \times 10^{-5}$
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Equilibrium	Some $-x$	$+x$	$+x$	$x = [\text{Ag}^+] = [\text{Cl}^-] = [\text{AgCl}]$
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Very important method

Very important method

Poll: Clicker Question 7

Given a generic formula, AX_2 , where A is the cation and X is the anion, and the molar solubility has been determined to be 1×10^{-4} M.

Calculate the value of the K_{sp} .

A. $K_{sp} = 1 \times 10^{-4}$

B. $K_{sp} = 1 \times 10^{-8}$

C. $K_{sp} = 2 \times 10^{-4}$

D. $K_{sp} = 4 \times 10^{-8}$

E. $K_{sp} = 4 \times 10^{-12}$



I some \emptyset \emptyset



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$$K_{sp} = [A^{2+}][X^-][X^-] = (y)(2y)(2y) = 4y^3 = 4(1 \times 10^{-4})^3$$

$$[A^{2+}][X^-]^2 = (y)(2y)^2$$

Which of the following compounds has the lowest molar solubility?

(least soluble)

A. $AgCl$ $K_{sp} = 1.8 \times 10^{-10} = [Ag^+][Cl^-] = x^2$

B. FeS $K_{sp} = 8 \times 10^{-19} = [Fe^{2+}][S^{2-}] = x^2$

C. LiF $K_{sp} = 1.8 \times 10^{-3} = [Li^+][F^-] = x^2$

D. $ZnSe$ $K_{sp} = 2 \times 10^{-25} = [Zn^{2+}][Se^{2-}] = x^2$

Which of the following compounds has the lowest molar solubility?

- A. AgCl $K_{sp} = 1.8 \times 10^{-10} = [Ag][Cl]$
- B. $Cd_3(PO_4)_2$ $K_{sp} = \sqrt[5]{2.5 \times 10^{-30}} = [Cd]^3 [PO_4]^2 = x^5$
- C. $Zn(OH)_2$ $K_{sp} = 3 \times 10^{-17} = [Zn][OH]^2$
- D. ZnSe $K_{sp} = \sqrt{2 \times 10^{-25}} = [Zn][Se] = x^2$

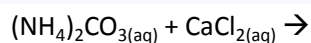
How did you know that so fast?

Quick way to estimate using your exponent math skills.

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Poll: Clicker Question 10

The net ionic equation for the following is:



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

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What did we learn today?

Solubility is an equilibrium condition.

Quantify the solubility using equilibrium constant, K .

K is "Ion Product" = product of the ions in solution

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Learning Outcomes

Understand the concept of the ion product.

Write formula unit, total ionic and net ionic reactions, and identify spectator ions.

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