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**[TP]** The expression for the equilibrium constant for the solubility equilibrium  $M_2X(s) \rightleftharpoons 2 M^+(aq) + X^{2-}(aq)$  is ...

25% 1.  $K_{sp} = (2 M^+) (X^{2-}) / (M_2X)$   
 25% 2.  $K_{sp} = (2 M^+)^2 (X^{2-}) / (M_2X)$   
 25% 3.  $K_{sp} = (2 M^+)^2 (X^{2-})$   
 25% 4.  $K_{sp} = (M^+)^2 (X^{2-})$

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Response Counter

5

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## Lecture 23 CH102 A1 (MWF 9:05 am)

Friday, March 24, 2017

- Review: Buffer action
- Ch15: Solubility, precipitation, and complexation

**Next lecture:** Complete ch15. Begin ch16: Electron transfer reactions and electrochemistry.  
 Please work through the notes "Balancing redox equations"  
<http://goo.gl/MMEUCs>

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### Different amounts of "not enough" base

At 25 °C, the pH of a 1.0 L solution pure water,  $K_a = 1 \times 10^{-14}$  is ...  
 pH = 7.00

Add 100. mL of 0.100 M HCl ...  
 $[H_3O^+] = 0.010 \text{ mol}/1.10 \text{ L} = 0.0091$   
 pH = 2.04 (huge change!)

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### Buffers

Mixtures of a weak acid and its conjugate base (or weak base and its conjugate acid) exhibit the special property that they **resist changes to pH**.

For this reason such mixtures are known as **buffers**.

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## Buffers resist change in pH

Added strong base (say,  $\text{OH}^-$ ) is gobbled up ...

$$\downarrow \text{HA}(aq) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O}(l) + \uparrow \text{A}^-(aq)$$

$c_a$  lowered,  $c_b$  raised,  $c_a/c_b$  lowered

Added strong acid (say, HCl) is gobbled up ...

$$\text{HCl}(aq) + \downarrow \text{A}^-(aq) \rightarrow \uparrow \text{HA}(aq) + \text{Cl}^-(aq)$$

$c_b$  lowered,  $c_a$  raised,  $c_a/c_b$  raised

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## Buffers resist change in pH

The relative amounts of weak acid (weak base) and conjugate acid (conjugate base) do not have to be equal.

The closer they are, the closer the pH will be to pKa.

The closer they are, the greater the amount strong base or strong base that can be "buffered."

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Ch15: Solubility, precipitation, and complexation

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## Solubility equilibria

$$\text{MX}_2(s) \rightleftharpoons \text{M}^{2+}(aq) + 2 \text{X}^-(aq), K = K_{\text{sp}}$$

Five kinds of problems

1. From solubility  $\rightarrow$  get  $K_{\text{sp}}$
2. From  $K_{\text{sp}}$   $\rightarrow$  get solubility
3. Solubility in presence of common ion
4. Will precipitation occur?
5. What remains after precipitation?

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**[TP]** At 25 °C,  $K_{sp}$  of  $\text{CaF}_2$   $3.9 \times 10^{-11}$ . What is the maximum number of moles of  $\text{CaF}_2$  that can dissolve in water at 25 °C?

17% 1. 0.002  
 17% 2. 0.01  
 17% 3. 0.0002  
 17% 4. 0.001  
 17% 5. 0.00002  
 17% 6. 0.0001

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### 1. From $K_{sp} \rightarrow$ get solubility

What is the **molar solubility** of  $\text{CaF}_2$ ?  $K_{sp} = 3.9 \times 10^{-11}$

$$\text{CaF}_2(s) \rightleftharpoons \text{Ca}^{2+}(aq) + 2 \text{F}^{-}(aq)$$

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### 1. From $K_{sp} \rightarrow$ get solubility

What is the **molar solubility** of  $\text{CaF}_2$ ?  $K_{sp} = 3.9 \times 10^{-11}$

$$\text{CaF}_2(s) \rightleftharpoons \text{Ca}^{2+}(aq) + 2 \text{F}^{-}(aq)$$

	$\text{MX}_2$	$\text{M}^{2+}$	$\text{X}^{-}$
Initial	excess	0	0
Change			
Equilibrium			

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### 1. From $K_{sp} \rightarrow$ get solubility

What is the **molar solubility** of  $\text{CaF}_2$ ?  $K_{sp} = 3.9 \times 10^{-11}$

$$\text{CaF}_2(s) \rightleftharpoons \text{Ca}^{2+}(aq) + 2 \text{F}^{-}(aq)$$

	$\text{MX}_2$	$\text{M}^{2+}$	$\text{X}^{-}$
Initial	excess	0	0
Change	$-x$	$+x$	$+2x$
Equilibrium	excess	$x$	$2x$

$$K_{sp} = (\text{M}^{2+})(\text{X}^{-})^2 = (x)(2x)^2 = 4x^3$$

Answer: 0.00021 mol/L

Check:  $0.00021 \times (2 \times 0.00021)^2 = 3.9 \times 10^{-11} = K_{sp}$

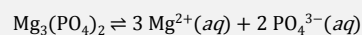
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2. From solubility → get  $K_{sp}$ 

The solubility of magnesium phosphate is 0.000259 g/(100 g) of water at 20 °C. Calculate its  $K_{sp}$  at this temperature.



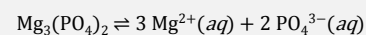
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2. From solubility → get  $K_{sp}$ 

The solubility of magnesium phosphate is 0.000259 g/100 g of water at 20 °C. Calculate its  $K_{sp}$  at this temperature.



	$\text{M}_3\text{X}_2$	$\text{M}^{2+}$	$\text{X}^{3-}$
Initial	excess	0	0
Change			
Equilibrium			



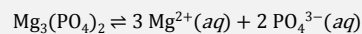
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2. From solubility → get  $K_{sp}$ 

The solubility of magnesium phosphate is 0.000259 g/100 g of water at 20 °C. Calculate its  $K_{sp}$  at this temperature.



	$\text{M}_3\text{X}_2$	$\text{M}^{2+}$	$\text{X}^{3-}$
Initial	excess	0	0
Change	-x	+3x	+2x
Equilibrium	excess	3x	2x

$$0.000259 \text{ g}/100 \text{ g} \rightarrow \text{mol}/\text{L} = x$$

$$K_{sp} = (\text{M}^{2+})^3(\text{X}^{3-})^2 = (3x)^3(2x)^2 = 108x^5$$

$$\text{Answer: } 1.00 \times 10^{-23}$$



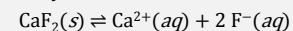
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## 3. Solubility in presence of common ion

The molar solubility of  $\text{CaF}_2$ ,  $K_{sp} = 3.9 \times 10^{-11}$ , is 0.00021 mol/L. Calculate the molar solubility in a solution of 0.015 M NaF.



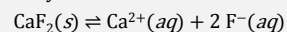
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### 3. Solubility in presence of common ion

The molar solubility of  $\text{CaF}_2$ ,  $K_{\text{sp}} = 3.9 \times 10^{-11}$ , is 0.00021 mol/L.  
Calculate the molar solubility in a solution of 0.015 M NaF.



	$\text{MX}_2$	$\text{M}^{2+}$	$\text{X}^-$
Initial			
Change			
Equilibrium			



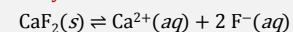
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### 3. Solubility in presence of common ion

The molar solubility of  $\text{CaF}_2$ ,  $K_{\text{sp}} = 3.9 \times 10^{-11}$ , is 0.00021 mol/L.  
**Calculate the molar solubility** in a solution of 0.015 M NaF.



	$\text{MX}_2$	$\text{M}^{2+}$	$\text{X}^-$
Initial	excess	0	$c_{\text{ion}}$
Change			
Equilibrium			



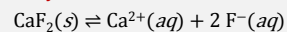
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### 3. Solubility in presence of common ion

The molar solubility of  $\text{CaF}_2$ ,  $K_{\text{sp}} = 3.9 \times 10^{-11}$ , is 0.00021 mol/L.  
**Calculate the molar solubility** in a solution of 0.015 M NaF.



	$\text{MX}_2$	$\text{M}^{2+}$	$\text{X}^-$
Initial	excess	0	$c_{\text{ion}}$
Change	$-x$	$+x$	$+2x$
Equilibrium	excess	$x$	$c_{\text{ion}} + 2x \approx c_{\text{ion}}$

$$K_{\text{sp}} = (\text{M}^{2+})(\text{X}^-)^2 = (x)(c_{\text{ion}})^2$$

Large  $c_{\text{ion}}$  makes  $x$  smaller

**Answer:**  $1.7 \times 10^{-7}$ , 0.08 % of the value in pure water!



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