

[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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Lecture 21 CH102 A1 (MWF 9:05 am)

Friday, March 16, 2018

- Review: $[H_3O^+]$ when different amounts of "not enough" base added

Ch15: Solubility, precipitation, and complexation
- Five kinds of solubility equilibria problems

Next lecture: Complete ch15: Practice with solubility equilibria; Begin ch16: Electron transfer reactions and electrochemistry.

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Different amounts of "not enough" base

At 25 °C, the pH of a 1.0 L solution of $c_a = c_b = 1.00$ M, $K_a = 1 \times 10^{-5}$ is …
pH = 5.00

Add 100. mL of 0.100 M NaOH …
HA → 1.00 mol – 0.010 mol = 0.99 mol
A^- → 1.00 mol + 0.010 mol = 1.01 mol
↓HA(*aq*) + $OH^-(aq) \rightarrow H_2O(l)$ + ↑$A^-(aq)$

The pH of a 1.0 L solution of c_a = 0.99 mol/1.10 L, c_b = 1.01 mol/1.10 L is …
c_a/c_b = 1.00 → 0.99/1.01, pH → 5.01 (tiny change!)

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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 NaOH …
$[OH^-]$ = 0.010 mol/1.10 L = 0.0091
pOH = 2.04, pH = 11.96 (huge change!)

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Different amounts of “not enough” base

At 25 ºC, the pH of a 1.0 L solution of $c_a = c_b = 1.00$ M, $K_a = 1 \times 10^{-5}$ is ...

pH = 5.00

Add 100. mL of 0.100 M HCl ...

HA → 1.00 mol + 0.010 mol = 1.01 mol

A^- → 1.00 mol – 0.010 mol = 0.99 mol

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

The pH of a 1.0 L solution of $c_a = 1.01$ mol/1.10 L, $c_b = 0.99$ mol/1.10 L ...

$c_a/c_b = 1.00 \rightarrow 1.01/0.99$, pH → 4.99 (tiny change!)

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Different amounts of “not enough” base

At 25 ºC, 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 ...

$[H_3O^+] = 0.010$ mol/1.10 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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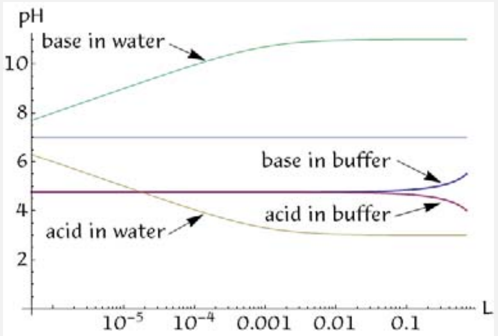
Buffers resist change in pH



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Buffers resist change in pH

Added strong base (say, OH^-) is gobbled up …

$\downarrow HA(aq) + OH^-(aq) \rightarrow H_2O(l) + \uparrow A^-(aq)$

c_a lowered, c_b raised, c_a/c_b lowered

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

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

c_b lowered, c_a raised, c_a/c_b raised

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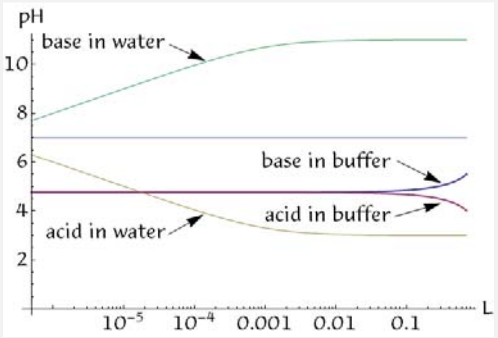
Buffers resist change in pH



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Ch15: Solubility, precipitation, and complexation

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Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2018

Solubility equilibria

$$MX_2(s) \rightleftharpoons M^{2+}(aq) + 2\,X^-(aq),\ K = K_{sp}$$

Five kinds of problems

1. From solubility → get K_{sp}
2. From K_{sp} → 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 CaF_2 is 3.9×10^{-11} . What is the maximum number of moles of 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

Response Counter

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1. From K_{sp} → get solubility

What is the molar solubility of CaF_2? $K_{sp} = 3.9 \times 10^{-11}$

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ F^{-}(aq)$$

1. From K_{sp} → get solubility

What is the molar solubility of CaF_2? $K_{sp} = 3.9 \times 10^{-11}$

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ F^{-}(aq)$$

	MX_2	M^{2+}	X^-
Initial	excess	0	0
Change			
Equilibrium			

1. From K_{sp} → get solubility

What is the molar solubility of CaF_2? $K_{sp} = 3.9 \times 10^{-11}$

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ F^{-}(aq)$$

	MX_2	M^{2+}	X^-
Initial	excess	0	0
Change	$-x$	$+x$	$+2x$
Equilibrium	excess	x	$2x$

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

Answer: 0.00021 mol/L

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

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.

$$Mg_3(PO_4)_2\,(s) \rightleftharpoons 3\,Mg^{2+}(aq) + 2\,PO_4^{3-}(aq)$$

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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.

$$Mg_3(PO_4)_2\,(s) \rightleftharpoons 3\,Mg^{2+}(aq) + 2\,PO_4^{3-}(aq)$$

	M_3X_2	M^{2+}	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.

$$Mg_3(PO_4)_2\,(s) \rightleftharpoons 3\,Mg^{2+}(aq) + 2\,PO_4^{3-}(aq)$$

	M_3X_2	M^{2+}	X^{3-}
Initial	excess	0	0
Change	$-\,x$	$+\,3\,x$	$+\,2\,x$
Equilibrium	excess	$3\,x$	$2\,x$

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

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

Answer: 1.00×10^{-23}

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3. Solubility in presence of common ion

The molar solubility of 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.

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\,F^-(aq)$$

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3. Solubility in presence of common ion

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$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ F^-(aq)$$

	MX_2	M^{2+}	X^-
Initial			
Change			
Equilibrium			

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3. Solubility in presence of common ion

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$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ F^-(aq)$$

	MX_2	M^{2+}	X^-
Initial	excess	0	c_{ion}
Change			
Equilibrium			

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3. Solubility in presence of common ion

The molar solubility of 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.

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ F^-(aq)$$

	MX_2	M^{2+}	X^-
Initial	excess	0	c_{ion}
Change	$-x$	$+x$	$+2x$
Equilibrium	excess	x	$c_{ion} + 2x \approx c_{ion}$

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

Large c_{ion} makes x smaller

Answer: 1.7×10^{-7}, 0.08 % of the value in pure water!

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