

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018 Copyright © 2018 Dan Dill dan@bu.edu

[TP] K_{sp} for $M_2X(s) \rightleftharpoons 2 M^+(aq) + X^{2-}(aq)$ is 8×10^{-11} . Assume a maximum of y moles of $M_2X(s)$ can dissolve in one liter. What is true for y ?

25% 1. $K_{sp} = (2y)(y)$
 25% 2. $K_{sp} = (2y)^2(y)$
 25% 3. $K_{sp} = (y)^2(y)$
 25% 4. None of the above

BOSTON UNIVERSITY Response Counter 5 1

Lecture 22 CH102 A2 (MWF 11:15 am)
 Wednesday, March 21, 2018

- Complete: Five kinds of solubility equilibria problems
- Practice with solubility equilibria

Next lecture: Begin ch16: Electron transfer reactions and electrochemistry.

For oxidation numbers and balancing redox equations, please work through <http://goo.gl/MMEUCs>

BOSTON UNIVERSITY

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018 Copyright © 2018 Dan Dill dan@bu.edu

Ch15: Solubility, precipitation, and complexation

BOSTON UNIVERSITY 5

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018 Copyright © 2018 Dan Dill dan@bu.edu

2. From solubility \rightarrow 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 | | | |

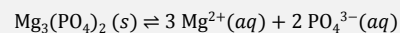
BOSTON UNIVERSITY 6

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

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.



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

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

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

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



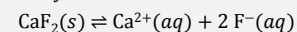
7

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

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.



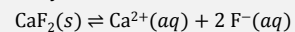
8

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

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.



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



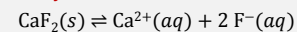
9

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

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.



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



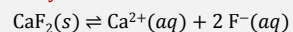
10

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

3. Solubility in presence of common ion

The molar solubility of 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.



| | MX_2 | M^{2+} | X^{-} |
|-------------|---------------|-----------------|--|
| Initial | excess | 0 | c_{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_{ion} makes x smaller

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



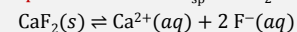
11

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

4. Will precipitation occur?

0.2 mmol of NaF and 10 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in a total volume of 1 L of water. Will a precipitate form? The K_{sp} of CaF_2 is 3.9×10^{-11} .



| | MX_2 | M^{2+} | X^{-} |
|---------|---------------|-----------------|----------------|
| Initial | | | |



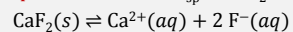
12

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

4. Will precipitation occur?

0.2 mmol of NaF and 10 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in a total volume of 1 L of water. Will a precipitate form? The K_{sp} of CaF_2 is 3.9×10^{-11} .



| | MX_2 | M^{2+} | X^{-} |
|---------|---------------|-----------------|----------------|
| Initial | 0 | c_{M} | c_{X} |

$$\text{Is } (\text{M}^{2+})(\text{X}^{-})^2 = (c_{\text{M}})(c_{\text{X}})^2 = Q_{\text{sp}} > K_{\text{sp}}?$$

If no, then no precipitation.

If yes, then a precipitate will form.

Answer: $Q_{\text{sp}} = 4 \times 10^{-10} > K_{\text{sp}}$, so $\text{CaF}_2(s)$ will precipitate



13

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

5. What remains after precipitation

When 0.2 mmol of NaF and 10 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in 1 L of water, $\text{CaF}_2(s)$ precipitates. How much Ca^{2+} and F^{-} remain in solution?
 K_{sp} of CaF_2 is 3.9×10^{-11} .



14

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

5. What remains after precipitation

When 0.2 mmol of NaF and 10 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in 1 L of water, $\text{CaF}_2(s)$ precipitates. **How much Ca^{2+} and F^- remain in solution?**
The K_{sp} of CaF_2 is 3.9×10^{-11} .

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



15

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

5. What remains after precipitation

When 0.2 mmol of NaF and 10.0 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in 1 L of water, $\text{CaF}_2(s)$ precipitates. **How much Ca^{2+} and F^- remain in solution?**
The K_{sp} of CaF_2 is 3.9×10^{-11} .

| | MX_2 | M^{2+} | X^- |
|-------------|---------------|-----------------|--------------|
| Initial mol | 0 | 0.0100 mol | 0.0002 mol |
| Revised M | | | |
| Change | | | |
| Equilibrium | | | |



16

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

5. What remains after precipitation

When 0.2 mmol of NaF and 10.0 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in 1 L of water, $\text{CaF}_2(s)$ precipitates. **How much Ca^{2+} and F^- remain in solution?**
The K_{sp} of CaF_2 is 3.9×10^{-11} .

| | MX_2 | M^{2+} | X^- |
|-------------|---------------|-----------------|--------------|
| Initial mol | 0 | 0.0100 mol | 0.0002 mol |
| Revised M | 0.0001 mol | 0.0099 mol/V | 0 |
| Change | | | |
| Equilibrium | | | |



17

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

5. What remains after precipitation

When 0.2 mmol of NaF and 10.0 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in 1 L of water, $\text{CaF}_2(s)$ precipitates. **How much Ca^{2+} and F^- remain in solution?**
The K_{sp} of CaF_2 is 3.9×10^{-11} .

| | MX_2 | M^{2+} | X^- |
|-------------|---------------|-----------------|--------------|
| Initial | 0 | 0.0100 mol | 0.0002 mol |
| Revised | 0.0001 mol | 0.0099 mol/V | 0/V |
| Change | -y | +y | +2y |
| Equilibrium | | | |



18

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

5. What remains after precipitation

When 0.2 mmol of NaF and 10.0 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in 1 L of water, $\text{CaF}_2(\text{s})$ precipitates. **How much Ca^{2+} and F^- remain in solution?**
The K_{sp} of CaF_2 is 3.9×10^{-11} .

| | MX_2 | M^{2+} | X^- |
|-------------|----------------------|------------------------|--------------|
| Initial | 0 | 0.0100 mol | 0.0002 mol |
| Revised | 0.0001 mol | 0.0099 mol/V | 0/V |
| Change | - y | + y | + 2 y |
| Equilibrium | ≈ 0.0001 mol | ≈ 0.0099 mol/V | 2 y |



19

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

5. What remains after precipitation

When 0.2 mmol of NaF and 10.0 mmol of $\text{Ca}(\text{NO}_3)_2$ are combined in 1 L of water, $\text{CaF}_2(\text{s})$ precipitates. **How much Ca^{2+} and F^- remain in solution?**
The K_{sp} of CaF_2 is 3.9×10^{-11} .

| | MX_2 | M^{2+} | X^- |
|-------------|----------------------|------------------------|--------------|
| Initial | 0 | 0.0100 mol | 0.0002 mol |
| Revised | 0.0001 mol | 0.0099 mol/V | 0/V |
| Change | - y | + y | + 2 y |
| Equilibrium | ≈ 0.0001 mol | ≈ 0.0099 mol/V | 2 y |

$$K_{\text{sp}} = (\text{M}^{2+})(\text{X}^-)^2 \approx (0.0099)(2y)^2$$

Answer: $[\text{Ca}^{2+}] = 0.0099 \text{ M}$, $[\text{F}^-] = 2y = 0.000063 \text{ M}$

Check: $Q_{\text{sp}} = (0.0099)(0.000063)^2 = 3.9 \times 10^{-11} = K_{\text{sp}}$



20

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

Practice with solubility equilibria



21

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

[TP] The expression for the equilibrium constant for the solubility equilibrium $\text{M}_2\text{X}(\text{s}) \rightleftharpoons 2 \text{M}^+(\text{aq}) + \text{X}^{2-}(\text{aq})$ is ...

- 25% 1. $K_{\text{sp}} = (2 \text{ M}^+) (\text{X}^{2-}) / (\text{M}_2\text{X})$
 25% 2. $K_{\text{sp}} = (2 \text{ M}^+)^2 (\text{X}^{2-}) / (\text{M}_2\text{X})$
 25% 3. $K_{\text{sp}} = (2 \text{ M}^+)^2 (\text{X}^{2-})$
 25% 4. $K_{\text{sp}} = (\text{M}^+)^2 (\text{X}^{2-})$



Response
Counter



22

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

[TP] K_{sp} for $M_2X(s) \rightleftharpoons 2 M^+(aq) + X^{2-}(aq)$ is 8×10^{-11} . Assume a maximum of y moles of $M_2X(s)$ can dissolve in one liter. What is true for y ?

- 25% 1. $K_{sp} = (2y)(y)$
 25% 2. $K_{sp} = (2y)^2(y)$
 25% 3. $K_{sp} = (y)^2(y)$
 25% 4. None of the above

Response
Counter

23

Lecture 22 CH102 A2 (MWF 11:15 am) Spring 2018

Copyright © 2018 Dan Dill dan@bu.edu

[Quiz] K_{sp} for $M_2X(s) \rightleftharpoons 2 M^+(aq) + X^{2-}(aq)$ is 8×10^{-11} . Assume a maximum of y moles of $M_2X(s)$ can dissolve in one liter. What is true for y if $M^+(aq)$ is initially 0.1 M (that is, M^+ is a common ion)?

- 20% 1. $K_{sp} \approx (2 \times 0.1)(y)$
 20% 2. $K_{sp} \approx (2 \times 0.1)^2(y)$
 20% 3. $K_{sp} \approx (0.1)^2(y)$
 20% 4. $K_{sp} \approx (0.1)(y)$
 20% 5. None of the above

Response
Counter

24