

**AP<sup>®</sup> CHEMISTRY**  
**2015 SCORING GUIDELINES**

**Question 4**

Answer the following questions about the solubility of  $\text{Ca(OH)}_2$  ( $K_{sp} = 1.3 \times 10^{-6}$ ).


(a) Write a balanced chemical equation for the dissolution of  $\text{Ca(OH)}_2(s)$  in pure water.

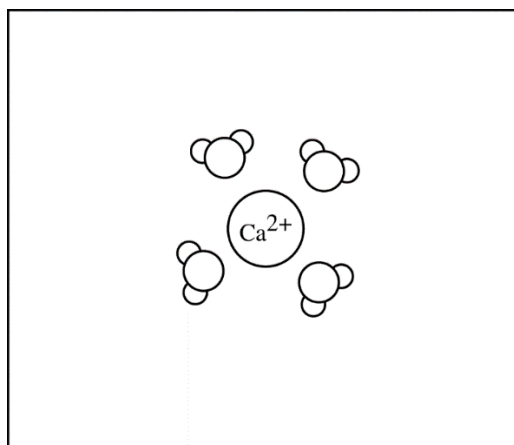
$\text{Ca(OH)}_2 \rightleftharpoons \text{Ca}^{2+} + 2 \text{OH}^-$	1 point is earned for the correct equation.
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(b) Calculate the molar solubility of  $\text{Ca(OH)}_2$  in  $0.10 \text{ M Ca(NO}_3)_2$ .

$K_{sp} = [\text{Ca}^{2+}] [\text{OH}^-]^2$ $1.3 \times 10^{-6} = (0.10 + x) (2x)^2 \approx (0.10) 4x^2 \quad [\text{assuming } x \ll 0.10]$ $1.3 \times 10^{-5} = 4x^2$ $x = 0.0018 \text{ M}$ <p>Molar solubility of <math>\text{Ca(OH)}_2 = 0.0018 \text{ M}</math></p>	<p>1 point is earned for the correct stoichiometry and setup.</p> <p>1 point is earned for the final answer.</p>
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(c) In the box below, complete a particle representation diagram that includes four water molecules with proper orientation around the  $\text{Ca}^{2+}$  ion.

Represent water molecules as 




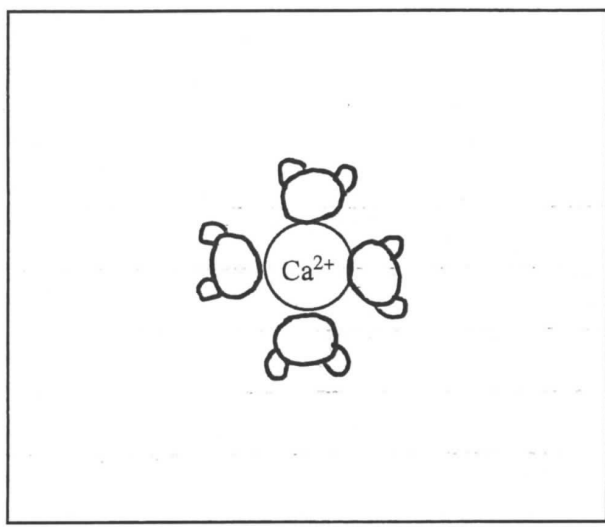
[The diagram should show the oxygen side of the water molecules oriented closer to the $\text{Ca}^{2+}$ ion.]	1 point is earned for a correct diagram that shows at least three of the four water molecules oriented as described.
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4. Answer the following questions about the solubility of  $\text{Ca(OH)}_2$  ( $K_{sp} = 1.3 \times 10^{-6}$ ).

- (a) Write a balanced chemical equation for the dissolution of  $\text{Ca(OH)}_2(s)$  in pure water.
- (b) Calculate the molar solubility of  $\text{Ca(OH)}_2$  in  $0.10 \text{ M Ca(NO}_3)_2$ .
- (c) In the box below, complete a particle representation diagram that includes four water molecules with proper orientation around the  $\text{Ca}^{2+}$  ion.

Represent water molecules as .



a.)  ~~$\text{Ca(OH)}_2(s) \rightarrow \text{Ca}^{2+} + 2\text{OH}^-$~~



b.)

$.10 \text{ mol Ca}^{2+}$	$\text{Ca(OH)}_2(s)$	$\rightarrow$	$\text{Ca}^{2+}$	$+ 2\text{OH}^-$
I	—		$.10 \text{ M}$	$0$
C	—		$+ x$	$-2x$
E	—		$.10 \text{ M} + x$	$2x$

$K_{sp} = [\text{Ca}^{2+}][\text{OH}^-]^2$

$1.3 \times 10^{-6} = (.10 + x)[2x]^2$

$x = .0018$

$.0018 \text{ mol/L}$

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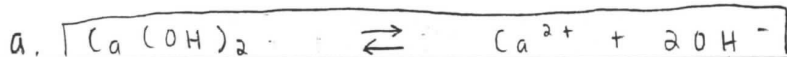
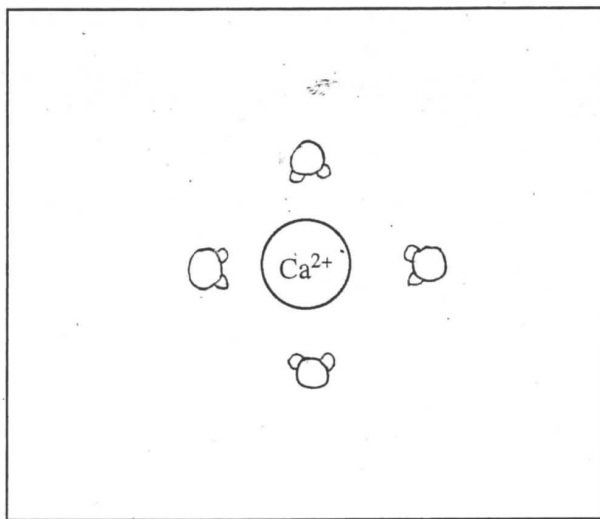
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4. Answer the following questions about the solubility of  $\text{Ca(OH)}_2$  ( $K_{sp} = 1.3 \times 10^{-6}$ ).

4B of 1

- (a) Write a balanced chemical equation for the dissolution of  $\text{Ca(OH)}_2(s)$  in pure water.
- (b) Calculate the molar solubility of  $\text{Ca(OH)}_2$  in  $0.10\text{ M Ca(NO}_3)_2$ .
- (c) In the box below, complete a particle representation diagram that includes four water molecules with proper orientation around the  $\text{Ca}^{2+}$  ion.

Represent water molecules as



b.  $1.3 \times 10^{-6} = [0.1 + s][2s]^2$

$1.3 \times 10^{-6} = 0.1(4s^2)$

$1.3 \times 10^{-5} = 4s^2$


$3.25 \times 10^{-6} = s^2$

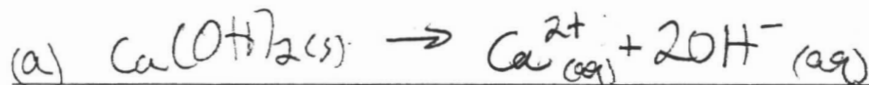
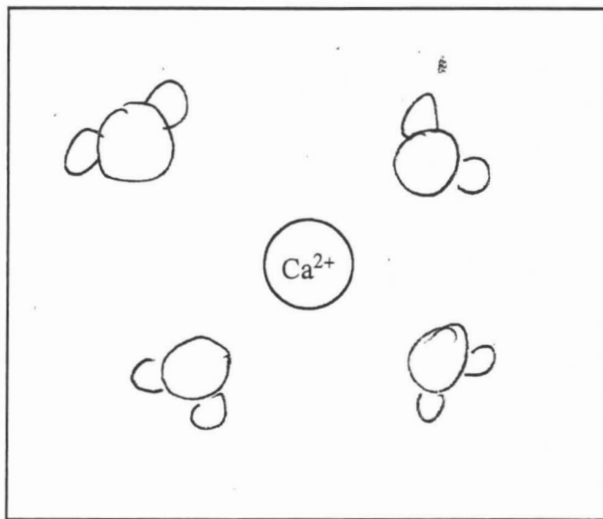
$s = 1.8 \times 10^{-3}$

4. Answer the following questions about the solubility of  $\text{Ca}(\text{OH})_2$  ( $K_{sp} = 1.3 \times 10^{-6}$ ).

4C 1 of 1

- (a) Write a balanced chemical equation for the dissolution of  $\text{Ca}(\text{OH})_2(s)$  in pure water.
- (b) Calculate the molar solubility of  $\text{Ca}(\text{OH})_2$  in  $0.10\text{ M Ca}(\text{NO}_3)_2$ .
- (c) In the box below, complete a particle representation diagram that includes four water molecules with proper orientation around the  $\text{Ca}^{2+}$  ion.

Represent water molecules as .



(b)  $1.3 \times 10^{-6} = \frac{(0.1 + x)(2x)}{x}$

$1.3 \times 10^{-6} x = 0.2x + 2x^2$

$1.3 \times 10^{-6} = 0.2 + 2x$

$-0.20 = 2x$

$x = -0.1$

**AP<sup>®</sup> CHEMISTRY**  
**2015 SCORING COMMENTARY**

**Question 4**

**Overview**

Question 4 assessed students' understanding of the solubility of an ionic solid. Students were asked to communicate this using various representations, including symbolic and particulate. In part (a) students wrote a balanced equation for the dissolution of  $\text{Ca(OH)}_2(s)$  in pure water. Part (b) assessed the students' ability to determine the molar solubility of  $\text{Ca(OH)}_2$  when a common ion is present in solution. In part (c) students drew a particulate representation of water molecules surrounding a calcium ion in solution.

**Sample: 4A**

**Score: 4**

One point was earned in part (a) for the correct balanced equation for the dissolution of  $\text{Ca(OH)}_2(s)$  in water. Two points were earned in part (b) for the correct inclusion of  $0.10\text{ M Ca}^{2+}$ , and for the setup and calculation of the molar solubility of  $\text{Ca(OH)}_2(s)$  in  $0.10\text{ M Ca(NO}_3)_2$  using the  $K_{sp}$  expression. One point was earned in part (c) for a drawing of properly oriented water molecules around the calcium ion.

**Sample: 4B**

**Score: 3**

One point was earned in part (a) for the correct equation for the dissolution of  $\text{Ca(OH)}_2(s)$  in water. In part (b) both points were earned for the correct setup and calculation of the molar solubility of  $\text{Ca(OH)}_2$ . No point was earned in part (c); in the particulate drawing the water molecules are oriented so the hydrogen atoms (positive dipole) are pointing toward the calcium ion.

**Sample: 4C**

**Score: 2**

One point was earned in part (a) for the correct equation. No points were earned in part (b). In the setup the student does not square the hydroxide ion concentration and includes  $x$  in the denominator of the  $K_{sp}$  expression, which indicates the inclusion of a concentration for  $\text{Ca(OH)}_2(s)$  in a heterogeneous equilibrium. One point was earned in part (c) for a correct particulate representation of the water molecules around the calcium ion.